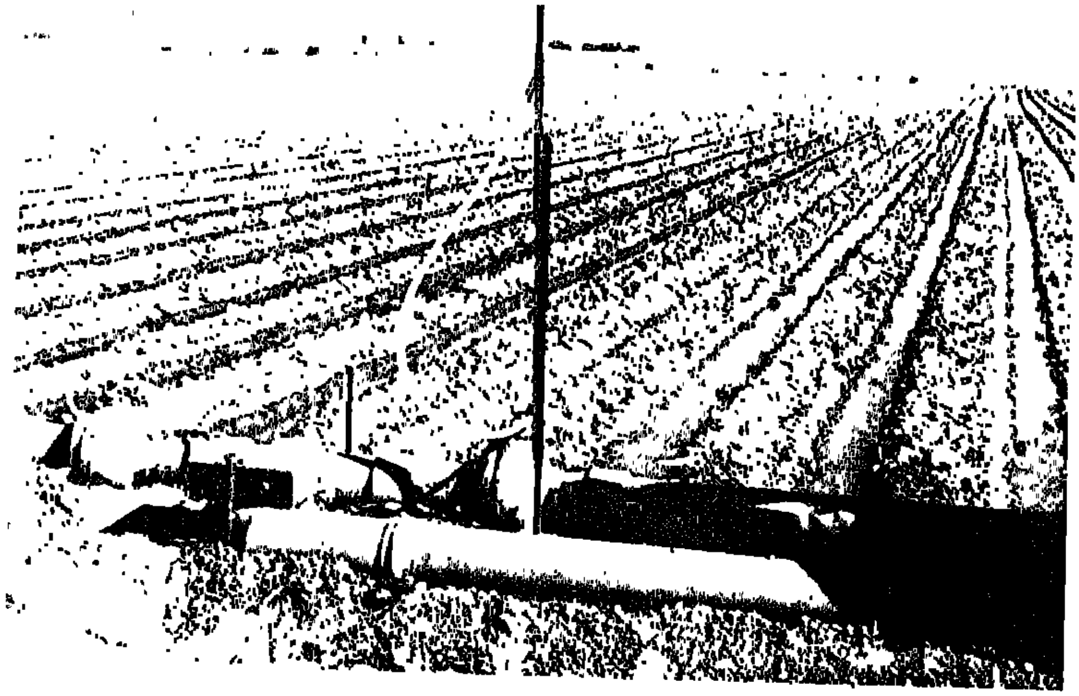
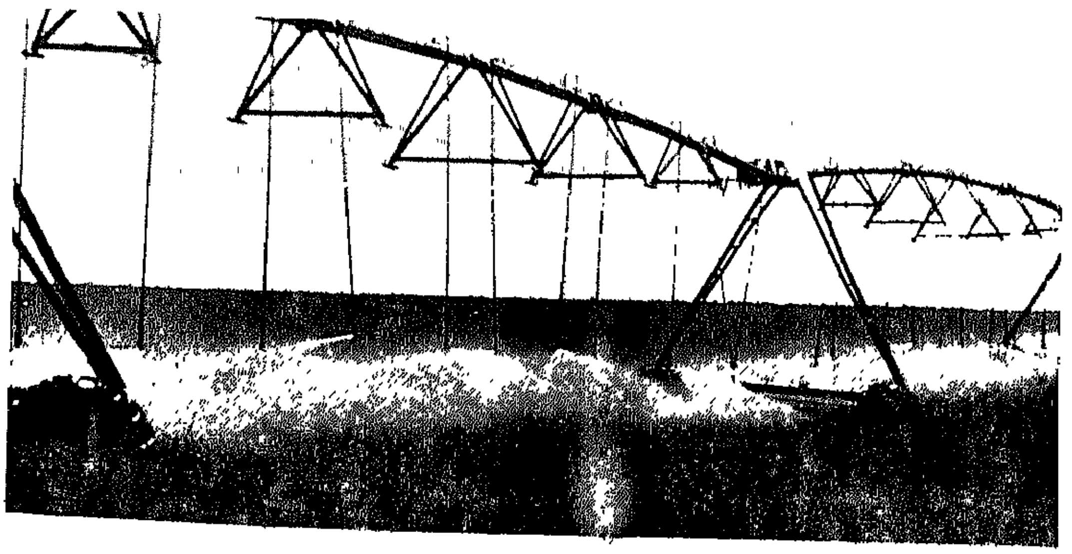
United States
Department of
Agriculture

SOIL CONSERVATION SERVICE

KANSAS IRRIGATION GUI[

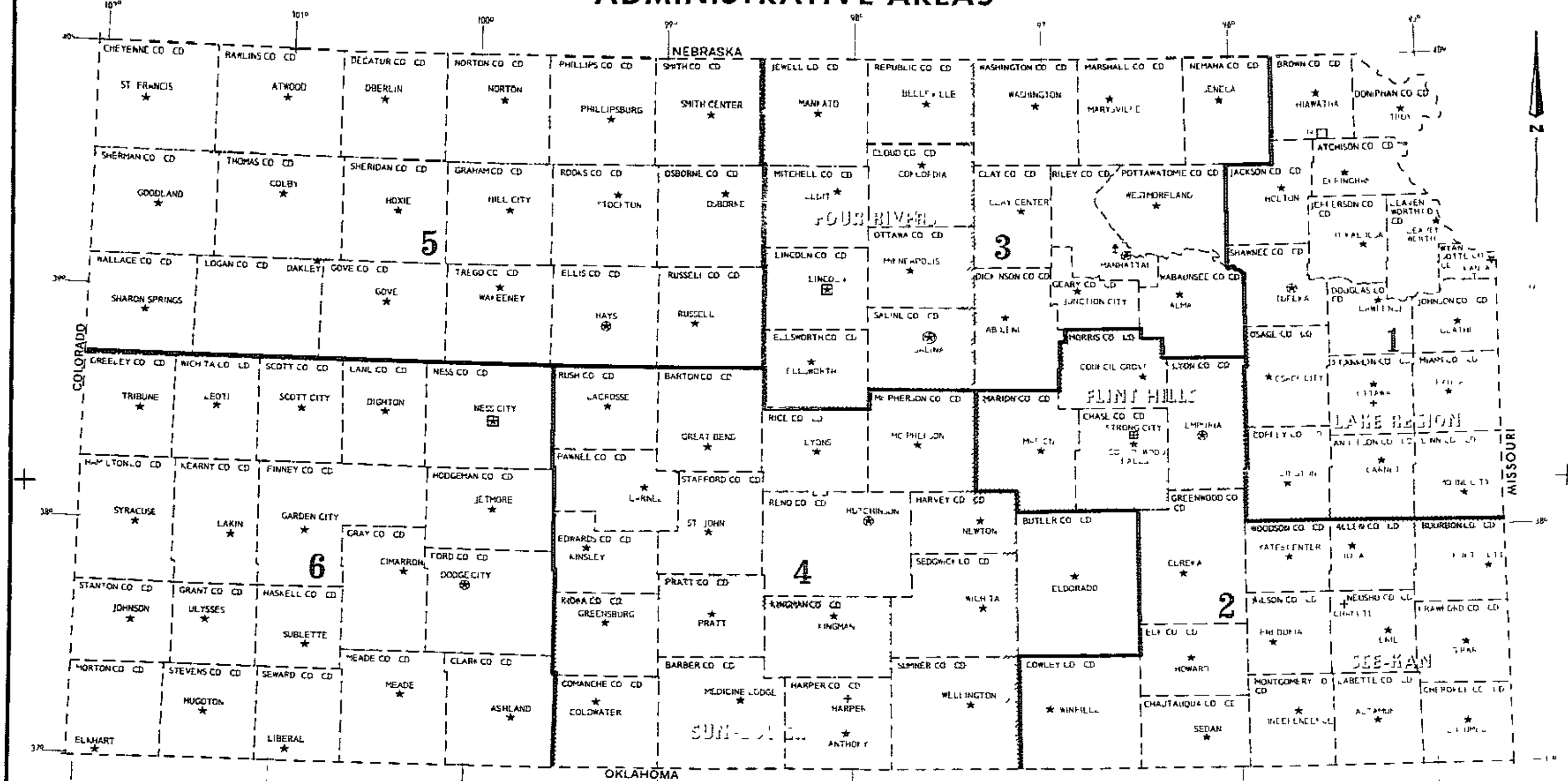




U S DEPARTMENT OF AGRICULTURE

SOIL CONSERVATION SERVICE

KANSAS CONSERVATION DISTRICTS, SCS FIELD OFFICES, PROJECT OFFICES, AND ADMINISTRATIVE AREAS



LEGEND

- STATE BOUNDARY
- COUNTY BOUNDARY
- STATE OFFICE SALINA
- AREA HEADQUARTERS
- ★ FIELD OFFICE
- 3 AREA NUMBER AND BOUNDARY
- PLANT MATERIALS CENTER
- G P C P BOUNDARY
- RC&D BOUNDARY
- + RC&D HEADQUARTERS
- WATERSHED PROJECT OFFICE

SOURCE
FAMILY OF MAPS DRWG NO 32 550 (11 73)
AND INFORMATION FROM FIELD TECHNICIANS
ALBERS EQUAL AREA PROJECTION

SCALE 0 10 20 30 40 50 60 70 MILES
0 20 40 60 80 100 120 KILOMETERS

CONSERVATION DISTRICTS SERVED

AREA I
TOPEKA

ANDERSON CO CD
ATCHISON CO CD
BROWN CO CD
COFFEY CO CD
DONIPHAN CO CD
DOUGLAS CO
FRANKLIN CO CD
JACKSON CO CD
JEFFERSON CO CD
JOHNSON CO CD
LEAVENWORTH CO CD
LINN CO CD
MIAMI CO CD
OSAGE CO CD
SHAWNEE CO CD
WYANDOTTE CO CD

AREA II
EMPORIA

ALLEN CO CD
BOURBON CO CD
CHASE CO CD
CHAUTAUQUA CO CD
CHEROKEE CO CD
COWLEY CO CD
CRAWFORD CO CD
ELK CO CD
GREENWOOD CO CD
LABETTE CO CD
LYON CO CD
MARION CO CD
MONTGOMERY CO CD
MORRIS CO CD
NEOSHO CO CD
WILSON CO CD
WOODSON CO CD

AREA III
MANHATTAN

CLAY CO CD
CLOUD CO CD
DICKINSON CO CD
ELLSWORTH CO CD
GEARY CO CD
JEWELL CO CD
LINCOLN CO CD
MARSHALL CO CD
MITCHELL CO CD
NEMAHA CO CD
OTTAWA CO CD
POTTAWATOMIE CO CD
REPUBLIC CO CD
RILEY CO CD
SALINE CO CD
WABAUNSEE CO CD
WASHINGTON CO CD

AREA IV
HUTCHINSON

BARBER CO CD
BARTON CO CD
BUTLER CO CD
COMANCHE CO CD
EDWARDS CO CD
HARPER CO CD
HARVEY CO CD
KINGMAN CO CD
KIOWA CO CD
McPHERSON CO CD
PAWNEE CO CD
PRATT CO CD
RENO CO CD
RICE CO CD
RUSH CO CD
SEDGWICK CO CD
STAFFORD CO CD
SUMNER CO CD

AREA V
HAYS

CHEYENNE CO CD
DECATUR CO CD
ELLIS CO CD
GOVE CO CD
GRAHAM CO CD
LOGAN CO CD
NORTON CO CD
OSBORNE CO CD
PHILLIPS CO CD
RAWLINS CO CD
ROOKS CO CD
RUSSELL CO CD
SHERIDAN CO CD
SHERMAN CO CD
SMITH CO CD
THOMAS CO CD
TREGO CO CD
WALLACE CO CD

AREA VI
DODGE CITY

CLARK CO CD
FINNEY CO CD
FORD CO CD
GRANT CO CD
GRAY CO CD
GREELEY CO CD
HAMILTON CO CD
HASKELL CO CD
HODGEMAN CO CD
KEARNY CO CD
LANE CO CD
MEADE CO CD
MORTON CO CD
NESS CO CD
SCOTT CO CD
SEWARD CO CD
STANTON CO CD
STEVENS CO CD
WICHITA CO CD

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5 S-32,774

United States
Department of
Agriculture

Soil
Conservation
Service

760 South Broadway
Salina, Kansas
67401

December 14, 1992

KANSAS IRRIGATION GUIDE NOTICE KS-15

Attached is a revised Part 5, Sprinkler Irrigation. Many changes and additions have been made to this part.

Design information for traveling guns, linear move sprinkler systems, and low pressure high application rate sprinkler systems (LEPA and others) was added. The minimum gross irrigation requirements for sprinkler tables have been expanded to include dry beans and sunflowers.

Form KS-ENG-22 on page 5-37 has been revised from a design/evaluation form to a strictly design form. For evaluations of center pivot systems, continue to use Form KS-ENG-22a.

- over -

A-2 (except Manhattan-1)
ENG(A)
PMC
Ness City PO
Coldwater (Irrigation Trailer)
F:

Abilene	Gove-2	Lincoln	St. John
Alma	Great Bend-2	Lyons-2	Salina
Anthony-2	Greensburg-2	Manhattan	Scott City-2
Ashland-2	Hays-2	Mankato-2	Seneca
Atwood-2	Hill City-2	Marysville-2	Sharon Springs-2
Belleville-2	Hoxie	McPherson	Smith Center-2
Beloit-2	Hugoton-2	Meade-2	Stockton-2
Cimarron-3	So. Hutchinson-2	Medicine Lodge-2	Sublette-2
Clay Center	Jetmore-2	Minneapolis-2	Syracuse-2
Coldwater-2	Johnson-2	Ness City-2	Tribune-2
Concordia	Junction City	Newton-2	Ulysses-2
Dighton-2	Kingman	Norton-2	WaKeeney-2
Dodge City-2	Kinsley-2	Oakley-2	Washington-2
El Dorado-2	LaCrosse-2	Osborne-2	Wellington-2
Ellsworth	Lakin-2	Phillipsburg-2	Westmoreland-2
Elkhart-2	Larned-2	Pratt-2	Wichita-2
Garden City-2	Leoti-2	Russell-2	
Goodland-2	Liberal-2	St. Francis-2	

REMOVE AND DESTROY OLD MATERIAL	DATED	INSERT NEW OR REVISED MATERIAL	DATED
Pages 5-1 and 2		Pages 5-1 through 5-53	12/92
Page 5-3	3/91		
Pages 5-4 through 5-18			
Pages 5-19 through 5-22	10/14/77		
Pages 5-23 through 5-24f	3/20/79		
Pages 5-24g through 5-24j	8/84		
Page 5-25			
Page 5-26	3/10/78		
Pages 5-27 through 30			
Pages 5-31 and 5-32	10/14/77		
Pages 5-33 through 5-36			

This transmittal should be destroyed after the above action has been taken and the amendment entered on the Kansas tabulation sheet.

James N. Habiger

James N. Habiger
State Conservationist

Attachments

TABULATION SHEET
IRRIGATION GUIDE FOR KANSAS NOTICES

Notice No.	Date	Rec'd Date	Pages Transmitted
1	8/5/75		Transmitted Irrigation Guide
2	4/29/76		Pen and ink changes to pages 1- 4-10, 6-13, and 7-1
3	10/14/77		Cover sheet, pages I to III, 1- 1-7, 1-8, 2-1 to 2-29, 4-9, 4-1 to 4-40, 5-19 to 5-24, 5-31, 5- 6-13, 6-14, 7-1, 7-2, and 7-5 to
4	3/10/78		Pages 5-3, 5-4, 5-4a, 5-25 and 5
KS-5	3/20/79		Pages I, II, 1-3 to 1-6, 4-5, 4- 5-23 to 5-24j, 7-1 to 7-10, 8-19
KS-6	10/19/79		Pages I to VI and 9-1 to 9-18
KS-7	4/12/82		Pages I to VI, 2-23 to 2-26, 5A- 5A-13, and 9-7 to 9-8
KS-8	3/23/83		Tabulation Sheet, pages I to VI, to 5A-10, 5A-13 to 5A-17
KS-9	8/17/84		Pages I to VI, 5-24g to 5-24j, a 10-1 to 10-18

TABULATION SHEET
IRRIGATION GUIDE FOR KANSAS NOTICES

Notice No.	Date	Rec'd Date	Pages Transmitted

I.G. Notice KS-8, 3-83

KANSAS IRRIGATION GUIDE
AND
IRRIGATION PLANNERS HANDBOOK

Table of Contents

Table of Contents (Cont.)

Tables

Number		Page

Figures

PART 1 - INTRODUCTION

A. General Information

This guide has been prepared to cover all areas of Kansas. One set of guidelines is considered adequate for the entire state except for differences that affect the irrigation requirements for crops. Seasonal net irrigation requirements are given for each county in Tables 2.1 and 2.2. Net irrigation requirements by months are given as a percent of seasonal total in Tables 2.3 and 2.4.

Guide material was developed to assist technicians and others working with Kansas irrigators in providing general planning criteria on various methods of irrigation commonly used in the state. When the system is installed and operated in accordance with basic data, the irrigator is assured that the irrigation system will be capable of supplying the amounts of water needed by plants for optimum production and that with proper seasonal adjustments irrigation water can be applied efficiently.

The irrigation planner must be aware that every irrigation system should minimize erosion, and that every system should account for drainage. Usually a desirable drainage system for gravity irrigation is the tailwater pit and pump-back system. The need for erosion control and drainage should be kept fully in mind when developing the conservation irrigation plan.

Recommendations relating to economic evaluation of irrigation are not accounted for in the guide. The economics of irrigation are usually an individual field or farm determination. The guide, however, does outline the limitations of irrigatior based on physical characteristics of the land.

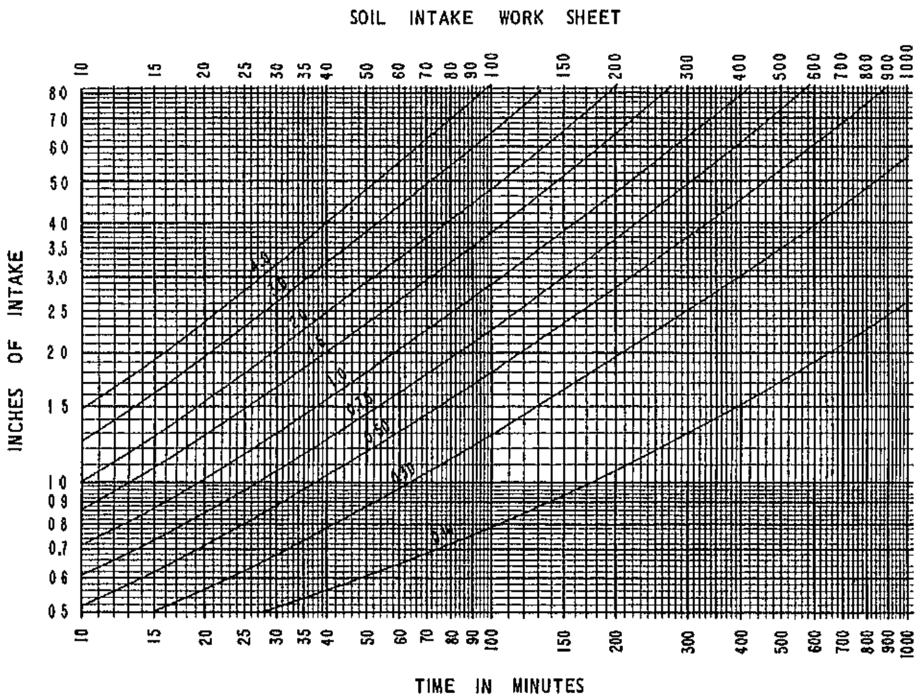
B. Soil Intake Family

Each kind of soil has its own wa
The difference in intake betwee'
for irrigation purposes severa'
In this guide, soil intake fam
0.5, 1.0, 1.5, 2.0 and 3.0, wi
representing the slowest intak
generally to the intake rate o
after several hours of water i
varies with time as intake con
and slowing to a fairly consta
So a soil listed in the 0.3 in
not necessarily take water at

at initial intake. For a light irrigation application of one inch the intake rate might be two or three times the index rate.

Each of the soil intake family groups relate to one of the intake family curves shown in Figure 1-1.

Figure 1-1 Intake Family Curves.



C. <u>Irrigation Design Groups</u>

In this guide the irrigated soils of Kansas are divided into 12 irrigation design groups. There are two groups each for soils in intake families 0.1, 0.3, 0.5, 1.0, and 1.5. The dividing difference in the 0.1 intake family is based on surface clayeyness or surface tightness. The dividing difference within each of the 0.3, 0.5 and 1.0 intake families is profile depth of soil.

The dividing point for 1.5 intake family is whether available water capacity is greater or less than 5 inches of water in 5 feet of soil profile. Irrigation design groups 11 and 12 are based on the intake family only.

D. Irrigation Specifications

Specifications for the commonly used methods of water application are given in Parts 4 and 5 of the guide. These include only methods commonly used in Kansas. The specific methods adapted for each soil group, each crop, and each slope group are listed, and applicable specifications are given.

The sprinkler irrigation specifications have not been shown in the irrigation design sheets because of the numerous sprinkler types available and their varied requirements. However, the suitability of sprinkler irrigation for use in each soil group, crop, and slope group is shown in the irrigation design sheets. Sprinkler criteria and installation guidance is given in Part 5.

Irrigation methods not commonly used in Kansas, such as subsurface, trickle (drip), or contour levee irrigation are not shown in the guide. Systems for these methods require special design and, if needed, will be handled on an individual basis.

E. Slope Groupings

Slopes were divided into groups for reasonable irrigation management and to prevent too great a spread for one set of recommendations. The slope ranges with the applicable design slope are shown below.

Slope Range Percent	Design Slope Percent
0.00 to 0.04	Level
0.05 to 0.14	0.1
0.15 to 0.25	0.2
0.26 to 0.55	
0.56 to 1.0	
1.1 to 2.0	
2.1 to 4.0	
4.1 to 8.0	

F. Control of Erosion

This guide contains the maximu
crop and method along with com

and contouring for the various soils under normal conditions to prevent excessive water erosion whether by irrigation or by rainfall. The guide also designates irrigation water application rates, stream sizes, length of run, and time of irrigation to minimize erosion.

The conservation treatment of irrigated land for wind and water erosion is listed in the Field Office Technical Guide, Section I-A.

G. Conservation Treatment Specifications

Section IV of the Field Office Technical Guide contains specifications for conservation treatment practices. Standards and specifications for such irrigation component practices as land leveling, underground irrigation pipeline, canal and ditch lining, farm irrigation structures, tailwater recovery systems, and the like are also found in Section IV of the Field Office Technical Guide.

H. Procedure Guide for Irrigation Land Development

1. The design of all irrigation systems shall follow the criteria in the Kansas Irrigation Guide and conform to the requirements outlined in the applicable Kansas standards and specifications.

2. The following basic information must be available or be provided for use in planning and design of any irrigation system:

   a. A water quality analysis * - provided by the irrigator

* Refer to Agriculture Handbook No. 60, "Diagnosis and Improvement of Saline and Alkali Soils," Chapter 5, Quality of Irrigation Water, and/or "Determining Water Quality for Irrigation," C-396, Revised November 1975, issued by the Kansas Cooperative Extension Service. Usual salinity limits of water are based on electrical conductivity (millimhos per centimeter) as follows:

$<$ 0.75 mmhos	- Safe water
0.75-2.25 mmhos	- Safe where drainage is adequate
$>$ 2.25 mmhos	- Very limited use on high salt tolerance crops in large quantities and very good subsoil drainage.

Note: Convert millimhos to micromhos by multiplying by 1,000. (0.75 mmhos x 1,000 = 750 micromhos)

b. Quantity of water available

c. Topographic or grid map

d. Soils information from Part 3 of the Kansas Irrigation Guide - If the soil is not listed in the guide, the soil scientist will make the following determinations in the field:

   (1) Effective soil depth, texture, permeability, slope, and the erosion and fertility potential.

   (2) Intake family with the effective rooting depth and water holding capacity.

   The soil scientist will then prepare a soils report and submit it to the State Soil Scientist for review. Upon his concurrence that the soil is suitable for irrigation, he will advise all field locations to list this information in the appropriate place in Part 3 of the Kansas Irrigation Guide.

3. In developing an overall irrigation system plan, the following guidelines should be observed and included:

   a. A conservation cropping system will be developed in accordance with the Kansas Standard and Specifications for Conservation Cropping System - 328. This may be listed on the Irrigation Development Plan or in the case file with adequate cross references.

   b. The amount of land to be developed for irrigation will depend on the planned cropping system, the intensity of irrigation desired by the irrigator, and the amount of irrigation water available.

   To determine the maximum irrigated acres, use the procedure outlined on page 1-7, Item I.2. This indicates the crop acres that can be completely irrigated throughout the growing season with no limitation of crop production due to moisture.

   In some cases, the irrigator may want or have to adjust his system operation to something less than maximum as far as pumping time and water use are concerned. Such

factors as high energy costs, restrictions on water use, type of cropping system, and other items may dictate this choice. Usually irrigations will be limited to several pre-selected times during critical crop growth periods. There may be other instances where the irrigator will use the same irrigation frequency, except he will use the maximum water available and adjust the irrigated acres accordingly.

If supplemental irrigation is planned, the amount of irrigated acres will usually be determined by the irrigation intensity desired. For example, in southeast Kansas where average annual rainfall is from 37 to 42 inches, the amount of irrigated acreage is usually based on providing one or two net applications from two to four inches. The primary purpose is to provide supplemental moisture during a week to 10-day dry period which usually occurs each summer at a critical stage of crop growth.

c. Lands subject to flood scour and/or deposition more frequent than once every 10 years should not be developed for irrigation.

d. Fields planned for land leveling shall meet the requirements of Kansas Standard and Specifications for Irrigation Land Leveling - 464.

e. Adequate drainage shall be provided in the irrigation plan as outlined in the Kansas Standard and Specifications for Irrigation Land Leveling - 464.

f. Tailwater recovery pits will be part of the irrigation plan if required under the conditions listed in the Kansas Standard and Specifications for Irrigation System, Tailwater Recovery - 447.

I. Irrigation Acreage Related to Water Supply

1. Farm Irrigation Efficiency - The condition of the land, water transmission lines, and system situation has a bearing on how efficiently water is delivered from the source to the field area. For gravity systems, the following farm efficiencies are generally applicable if the irrigation system is managed to where the amount of water applied will meet but not exceed the consumptive use rates of the crops being grown.

Farm Irrigation Efficiency	Irrigation System Condition
50%	Average system no treatment.
60%	Partial treatment i.e., Land Leveling or Irrigation Pipeline, etc.
70%	Land Leveling, Delivery Pipeline and Drainage System to design standards.
85%	Tailwater Recovery System with proper land leveling, delivery pipeline and drainage system.

Sprinkler efficiencies are shown in Table 5.1, page 5-1.

2. Area the Water Supply will Irrigate - Water supply related to irrigation acreage can vary considerably with farm conditions and management situations. The relationship stated below is a general recommendation only.

The following chart gives a factor value (F) to establish a relationship of water delivery volume to acres that can be irrigated as expressed by the formula --

Maximum Irrigated Acres = Well g.p.m. x F

Delivery Efficiency	Summer Irrigation Factor F	Winter Irrigation Factor F
50%	.10	.20
60%	.12	.24
70%	.14	.28
85%	.17	.34

Example - Well delivers 1200 g.p.m
in both summer and winter is pro
ground pipe and surface gated pi
drainage, i.e. 70% delivery effi

Maximum area that can be irrigat

1200 x 0.14 = 168 acres

Maximum area that can be irrigat

1200 x 0.28 = 336 acres

Maximum area that can be irrigat
double summer acreage -

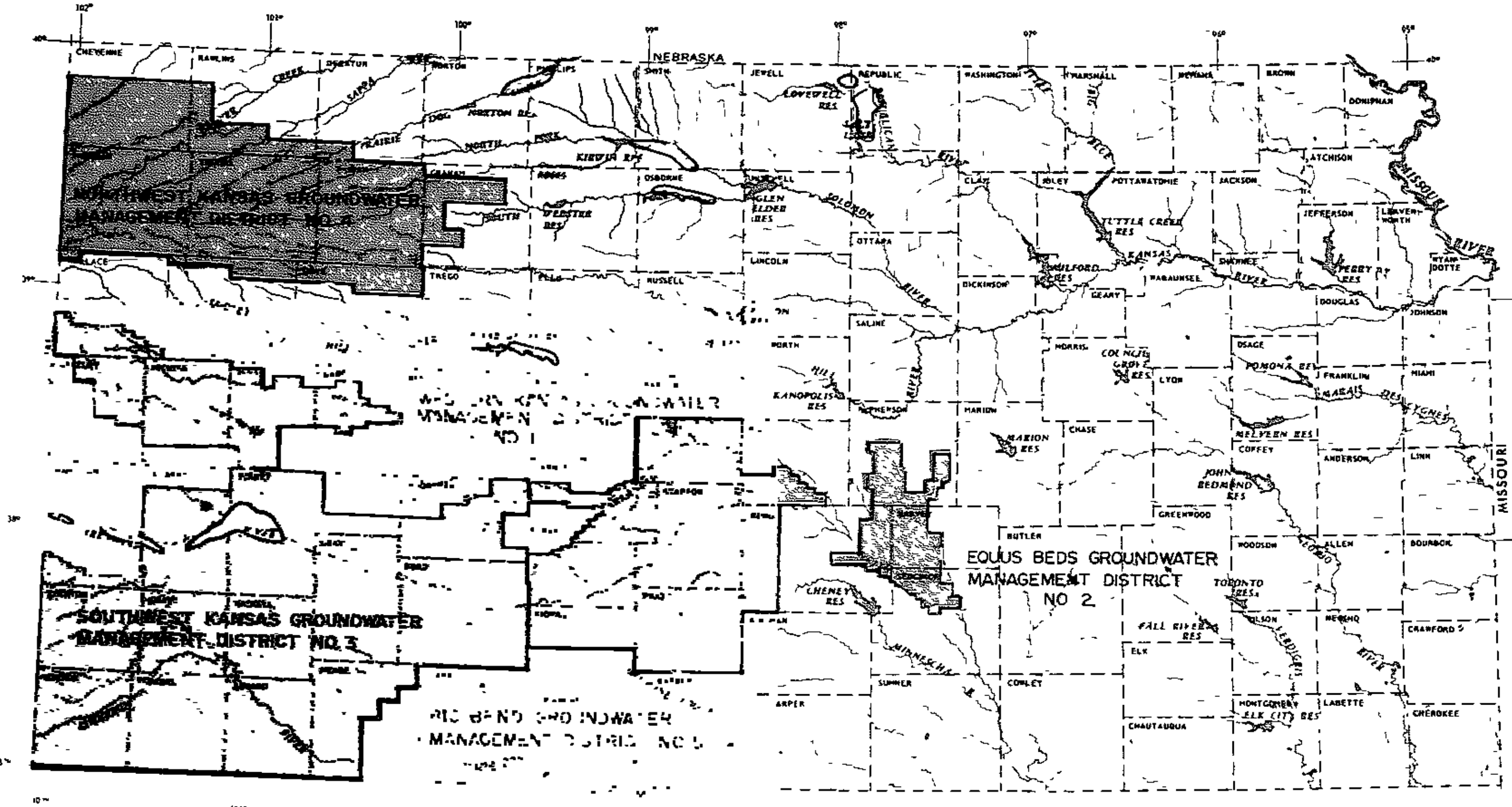
168 + 336 = 504 acres

U S DEPARTMENT OF AGRICULTURE

SOIL CONSERVATION SERVICE

KANSAS

ORGANIZED WATER MANAGEMENT AREAS RELATED TO IRRIGATION



IRRIGATION DIVERSION FEDERAL PROJECTS
IRRIGATION DIVERSION NON-FEDERAL
GROUNDWATER MANAGEMENT DISTRICTS

FIGURE I-2

SOURCE
SCS DRAWING 5,S-32,550 AND
INFORMATION FROM FIELD TECHNICIANS
ALBERS EQUAL AREA PROJECTION

SCALE 1:3,178,500

REV 6-16-77
5,0-35,096

PART 2 - CROPS

A. General Information

When crop stress from moisture shortage is eliminated by proper and timely irrigation, other factors become inhibitors to production. These factors include poor soil structure and tilth, low fertility, poor stands, weeds, insects and diseases. Much of the water applied through irrigation may be wasted unless sound farming practices are followed.

Soil structure and tilth must be favorable in order to have good aeration, good initial water intake, and good soil permeability. Tilth and structure can be maintained or improved by avoiding cultivation of wet fields, addition of manure or plowing under green manure crops, using grass and legumes in rotation, stubble mulching, and minimum tillage. On irrigated pastures, cattle should be excluded until surface soil is dry after irrigation.

Low fertility or an imbalance of nutrients are often the limiting factors on irrigated land. The well fed plant uses water much more efficiently than a plant that is starved or lacking in some nutrient element. Total water use by a healthy, well fed plant is greater than for a plant deprived of plant food, but the production per unit of water is much greater for the well fed plant. Fertility problems should be corrected by the application of barnyard manure and commercial fertilizer. Soil tests, observations, and field experience help determine the type and amount of fertilizer to use. Crop quality may be more important than crop production in some instances. Quality can usually be improved by proper fertility.

Adequate moisture and fertility and good soil physical condition will not insure high production unless the irrigation farmer controls weeds or pests, uses high quality seed of adapted varieties, and uses timely operations. We
and diseases usually are a greater problem
than on dryland. Crops and varieties sh
fit the soil and the irrigation system.
should be increased in most cases t
added by irrigation.

B. Net Irrigation Requirements (NIR)

1. Seasonal NIR Values - In developing net irrigation requirement values for Kansas there were several agencies and groups that gave input and consultations. Kansas State University through its experiment stations furnished data to assist in developing crop consumptive use values. The 1941-1970 rainfall record was used as a basis for rainfall values. This data furnished by the Kansas Water

Resources Board included a rainfall record for each county for each month of the 30-year period. Moisture accumulation in the soil profile during the crop dormant or non-growing season herein called "carryover" was estimated to be zero in Zone 1 in the southwest (see Figure 2-8) and increasing by 0.5 inch for each zone to 3.0 inches for Zone 7 on the east border.

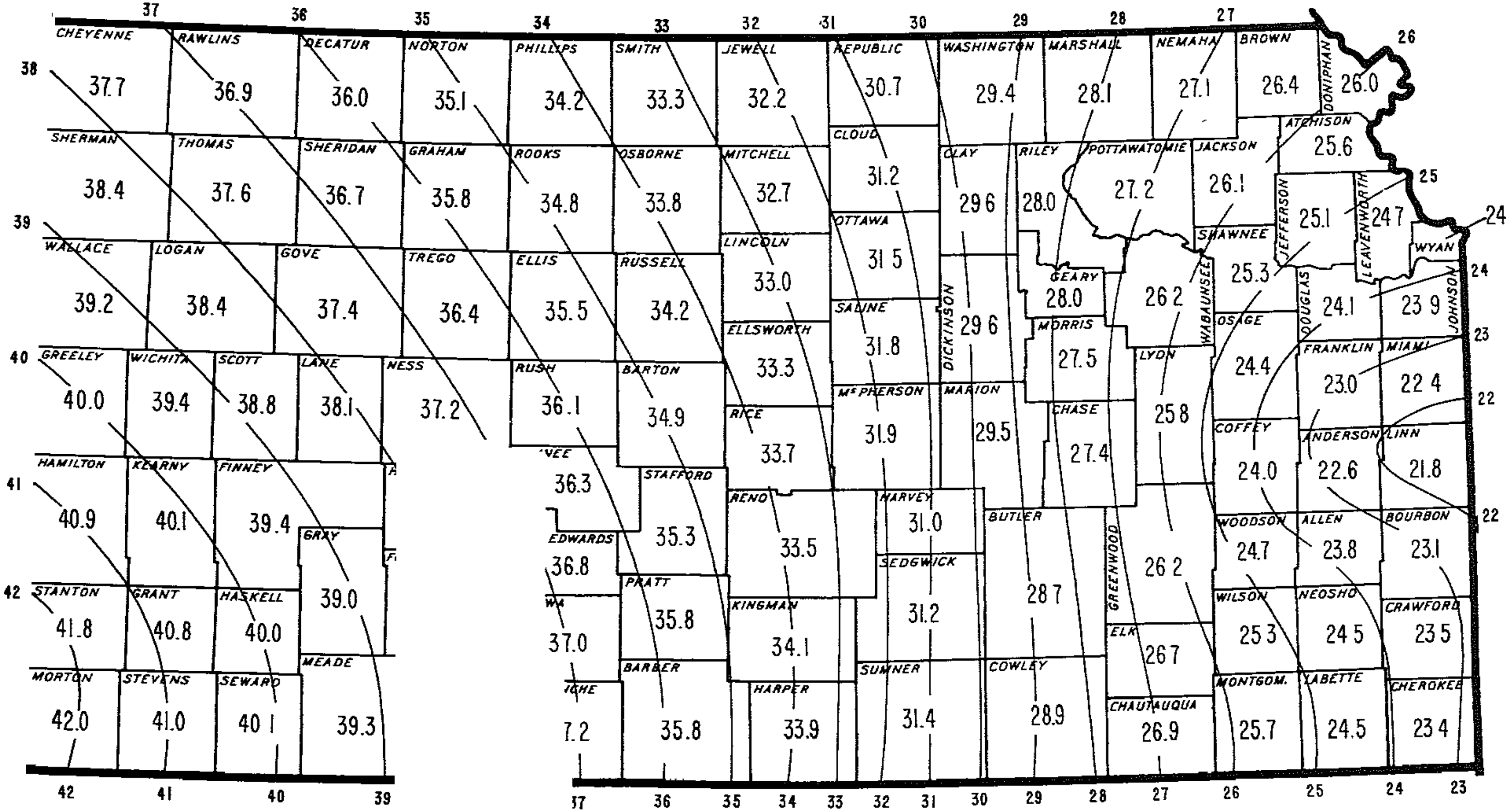
With crop consumptive use, carryover and rainfall values available, the criteria outlined in Soil Conservation Service Technical Release 21 was used to develop seasonal net irrigation requirements for each crop for each county on both the 80 percent chance and 50 percent chance rainfall conditions.

Seasonal net irrigation requirements on the 80 percent chance rainfall were adjusted to seasonal gross irrigation requirements (GIR) assuming 65 percent irrigation efficiency. These GIR values were considered representative of maximum seasonal irrigation water demand for general conditions. Computed GIR values for each county were placed on a state map then minor adjustments were injected so that lines of equal GIR values fit in a smooth progression across the state. GIR values being larger were used in preference to the NIR values for the smoothing process. Plus and minus adjustments were equalized in each third portion of the state (west, middle, and east) so that adjustments were reasonably balanced. The result is the "Seasonal Gross Irrigation Requirements" charts, Figures 2-1 through 2-7, pages 2-3 through 2-9. The Division of Water Resources, Kansas Department of Agriculture, expects to use these or similar charts in considering water rights allocations.

SCS did much of the computations and adjustment procedures. However, in addition to the agencies mentioned above the KSU Agricultural Engineering Department, KSU Extension Service, USDI Bureau of Reclamation and representation from each of five newly organized Kansas groundwater management districts made recommendations and contributed to the NIR development process.

Net irrigation requirement is the water need of the specified crop over and above effective rainfall and carryover soil moisture. Table 2.1, pages 2-13 and 2-14, gives the values for seasonal net irrigation requirements, based on 80 percent chance rainfall, for each county for each crop named. Likewise Table 2.2, pages 2-15 and 2-16, gives the values for seasonal net irrigation requirements based on average on 50 percent chance rainfall. The 80 percent chance rainfall, that which can be expected to be equaled or exceeded in 8 years out of 10, is, of course, a lesser amount of rainfall than the 50 percent chance rainfall

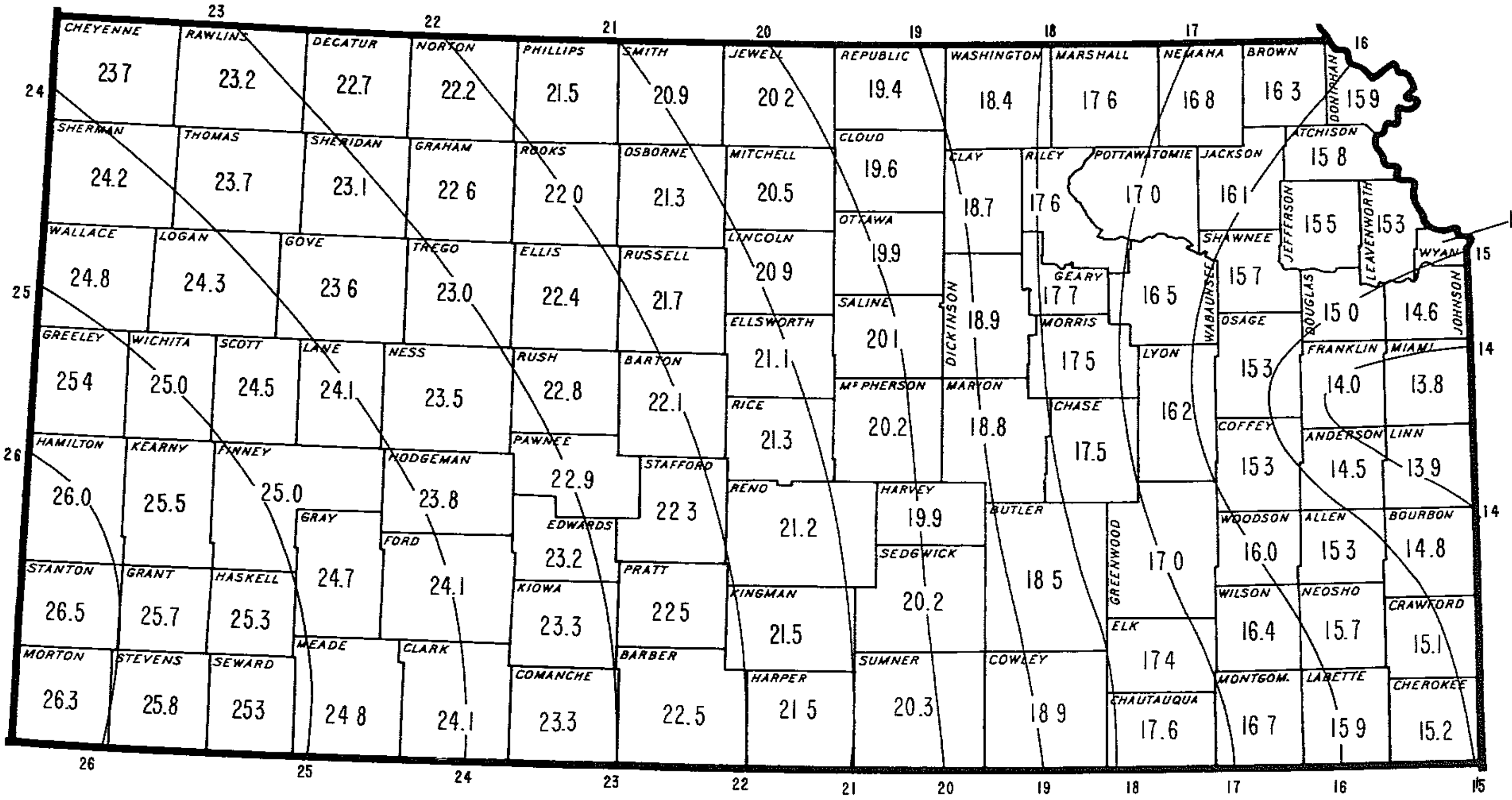
SEASONAL GROSS IRRIGATION REQUIREMENTS (INCHES)
80 Percent Chance Rainfall - 65 Percent Irrigation Efficiency



ALFALFA

FIG 2-1

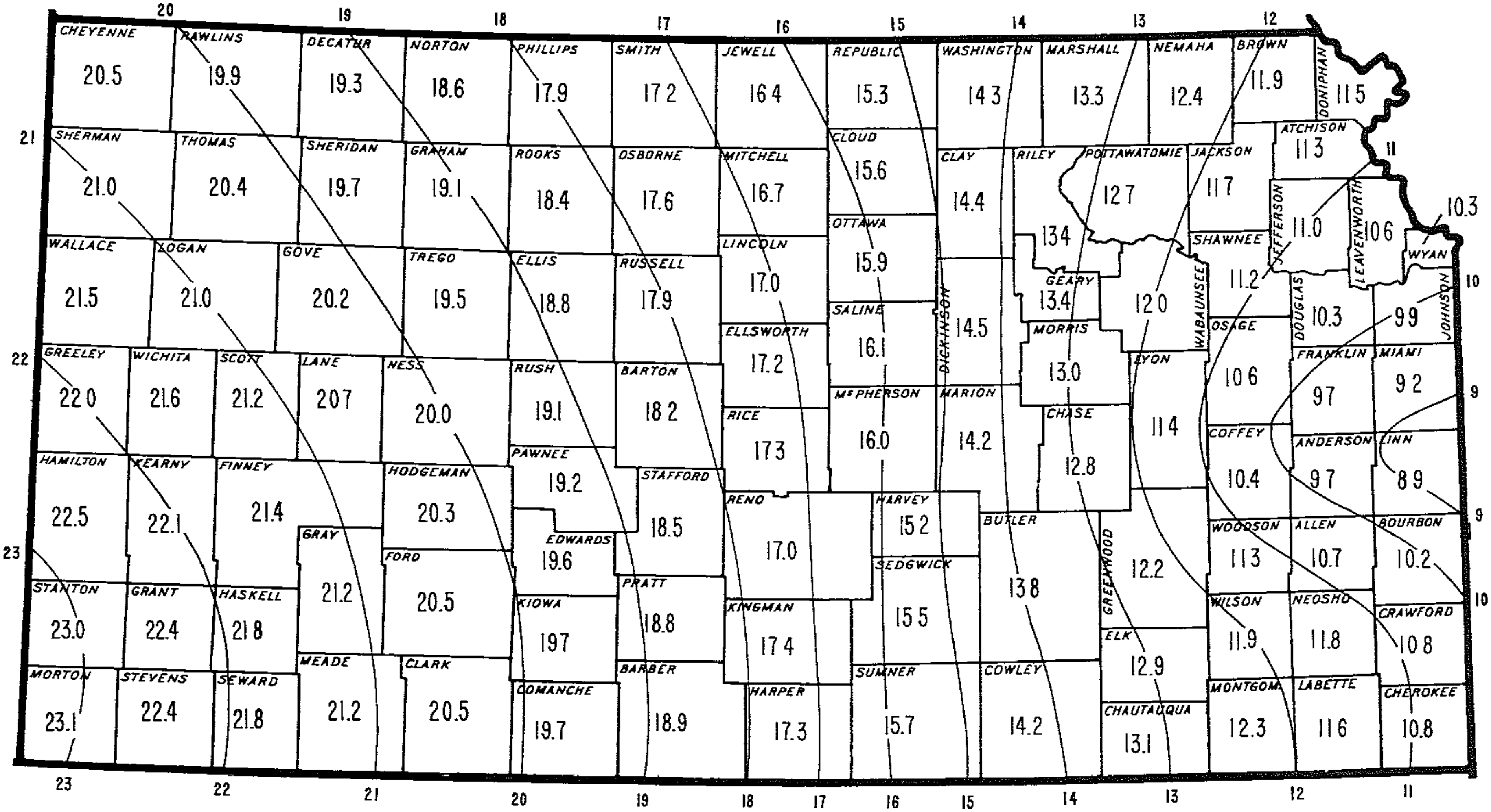
SEASONAL GROSS IRRIGATION REQUIREMENTS (INCHES)
80 Percent Chance Rainfall - 65 Percent Irrigation Efficiency



CORN

FIG 2-2

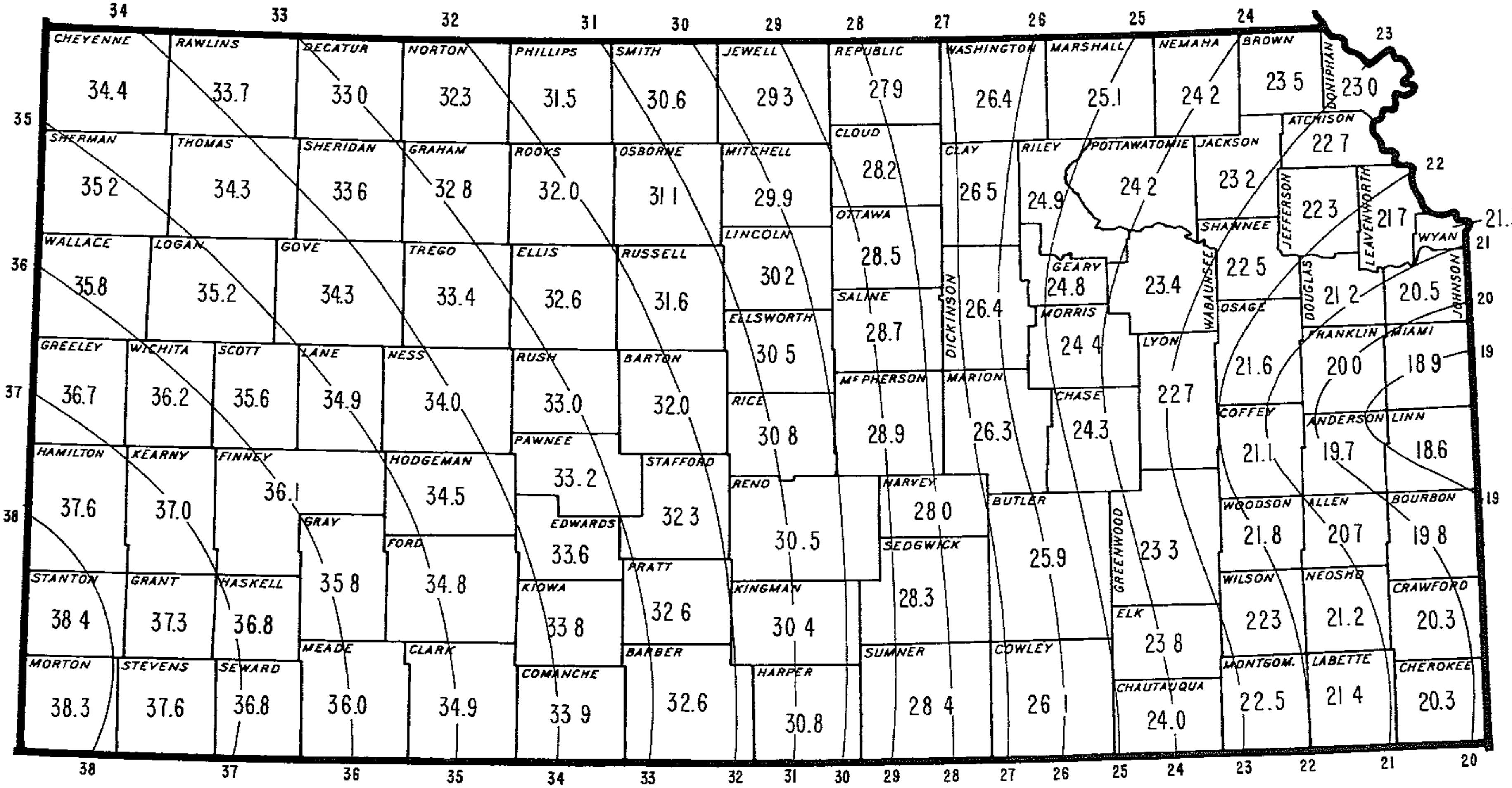
SEASONAL GROSS IRRIGATION REQUIREMENTS (INCHES)
80 Percent Chance Rainfall - 65 Percent Irrigation Efficiency



SORGHUM

FIG 2-3

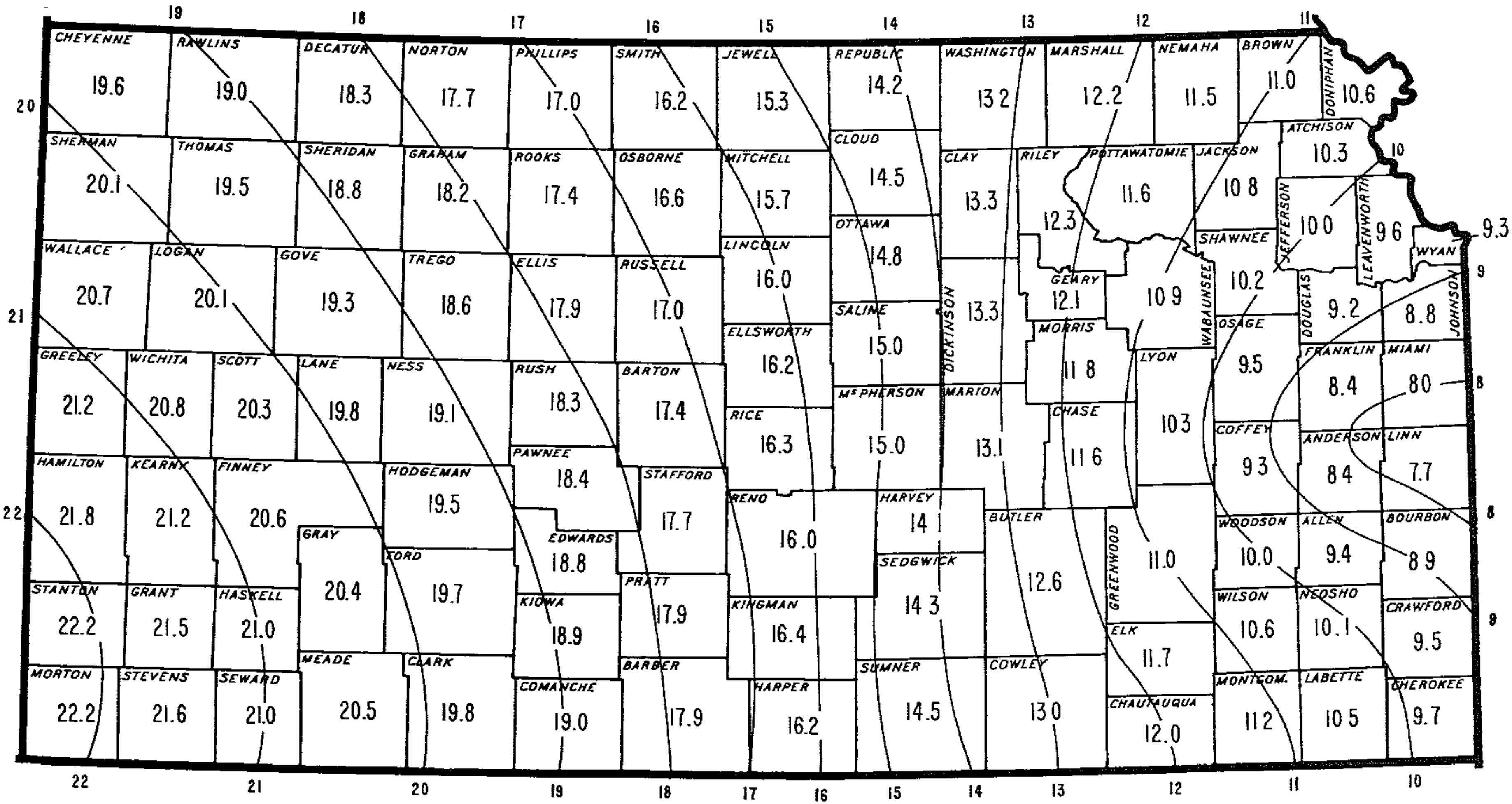
SEASONAL GROSS IRRIGATION REQUIREMENTS (INCHES)
80 Percent Chance Rainfall - 65 Percent Irrigation Efficiency



TAME GRASS

FIG 2-4

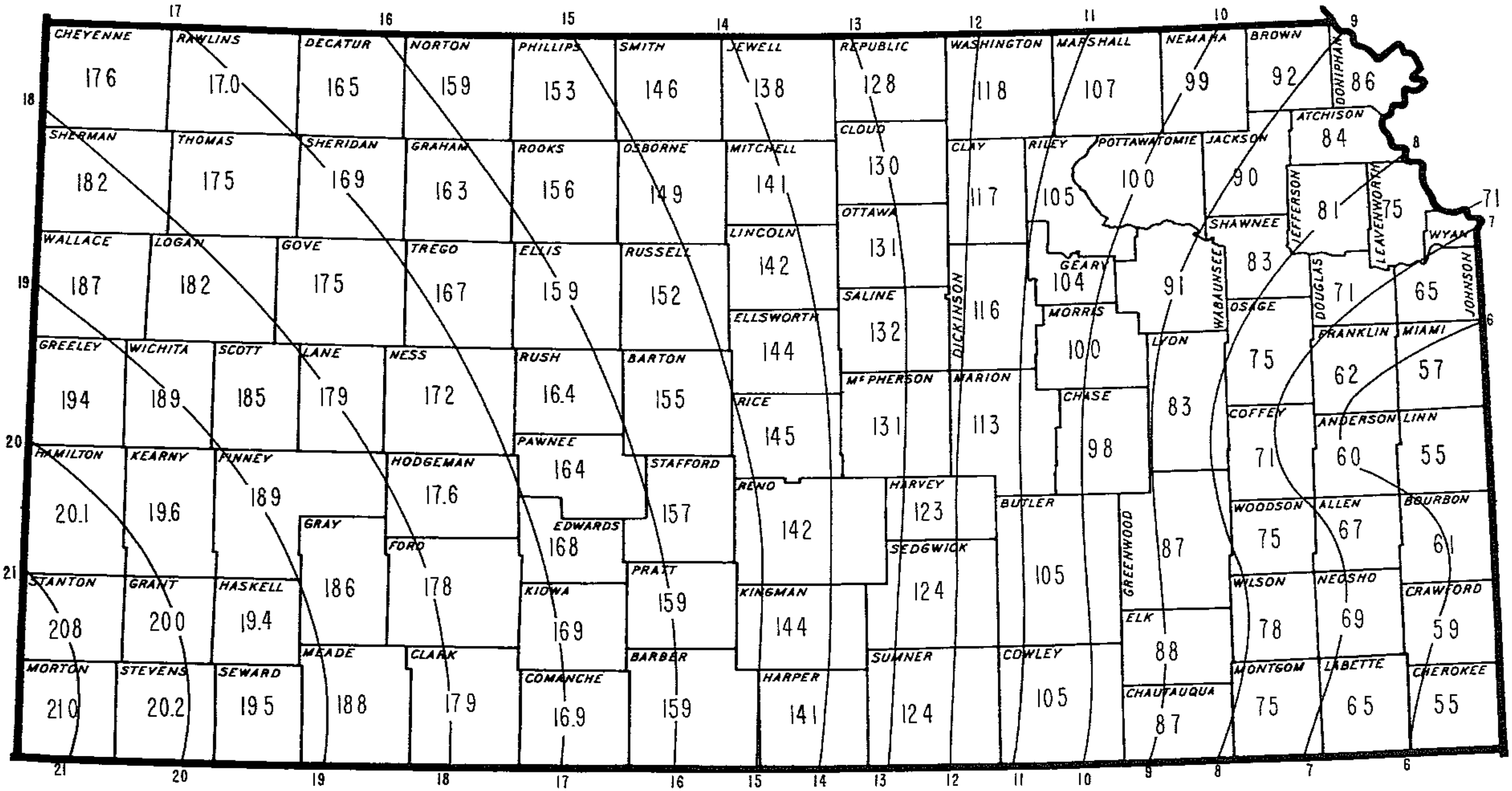
SEASONAL GROSS IRRIGATION REQUIREMENTS (INCHES)
80 Percent Chance Rainfall - 65 Percent Irrigation Efficiency



SOYBEANS

FIG 2-5

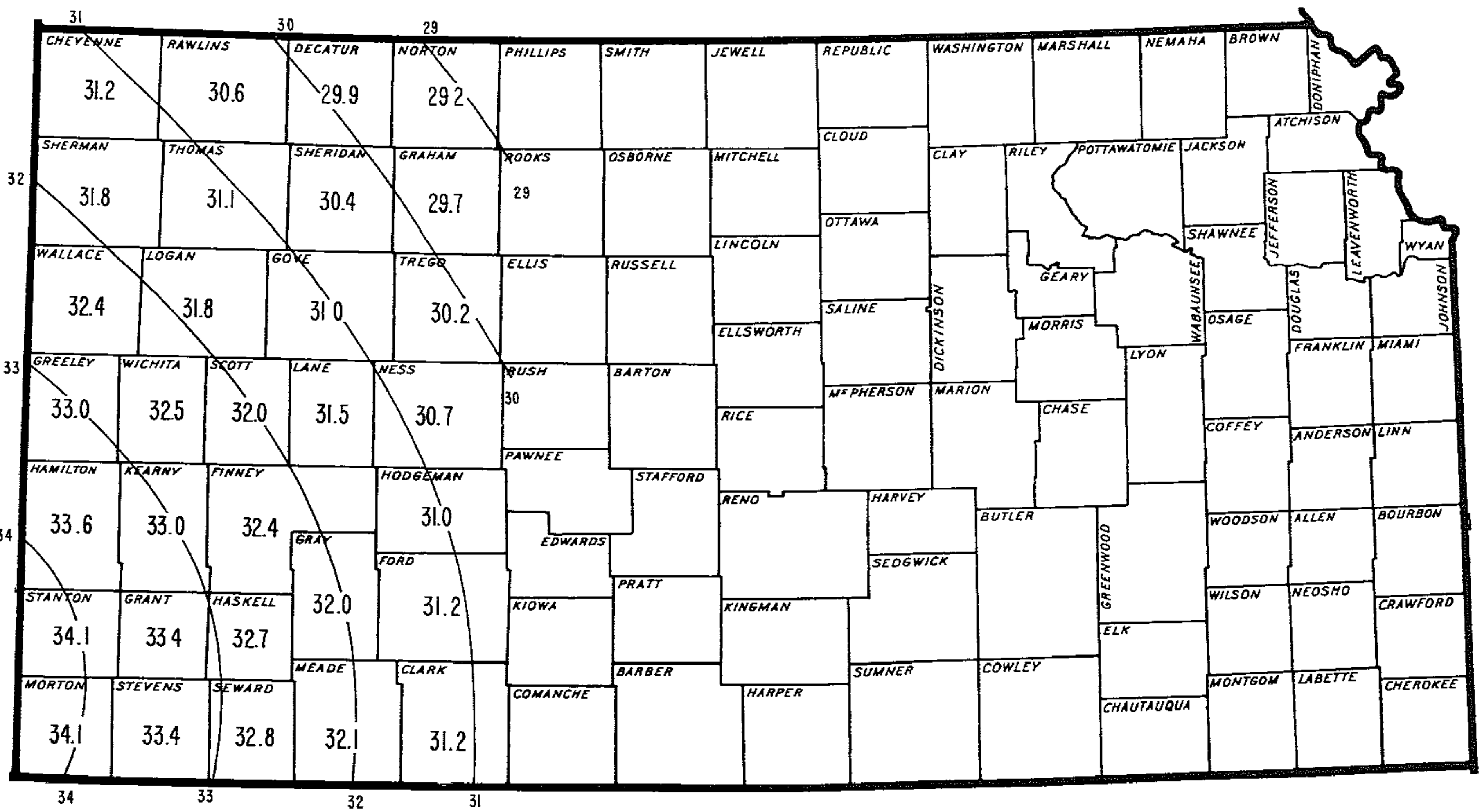
SEASONAL GROSS IRRIGATION REQUIREMENTS (INCHES)
80 Percent Chance Rainfall - 65 Percent Irrigation Efficiency



WHEAT

FIG 2-6

SEASONAL GROSS IRRIGATION REQUIREMENTS (INCHES)
80 Percent Chance Rainfall - 65 Percent Irrigation Efficiency



SUGAR BEETS

FIG 2-7

IRRIGATION ZONES

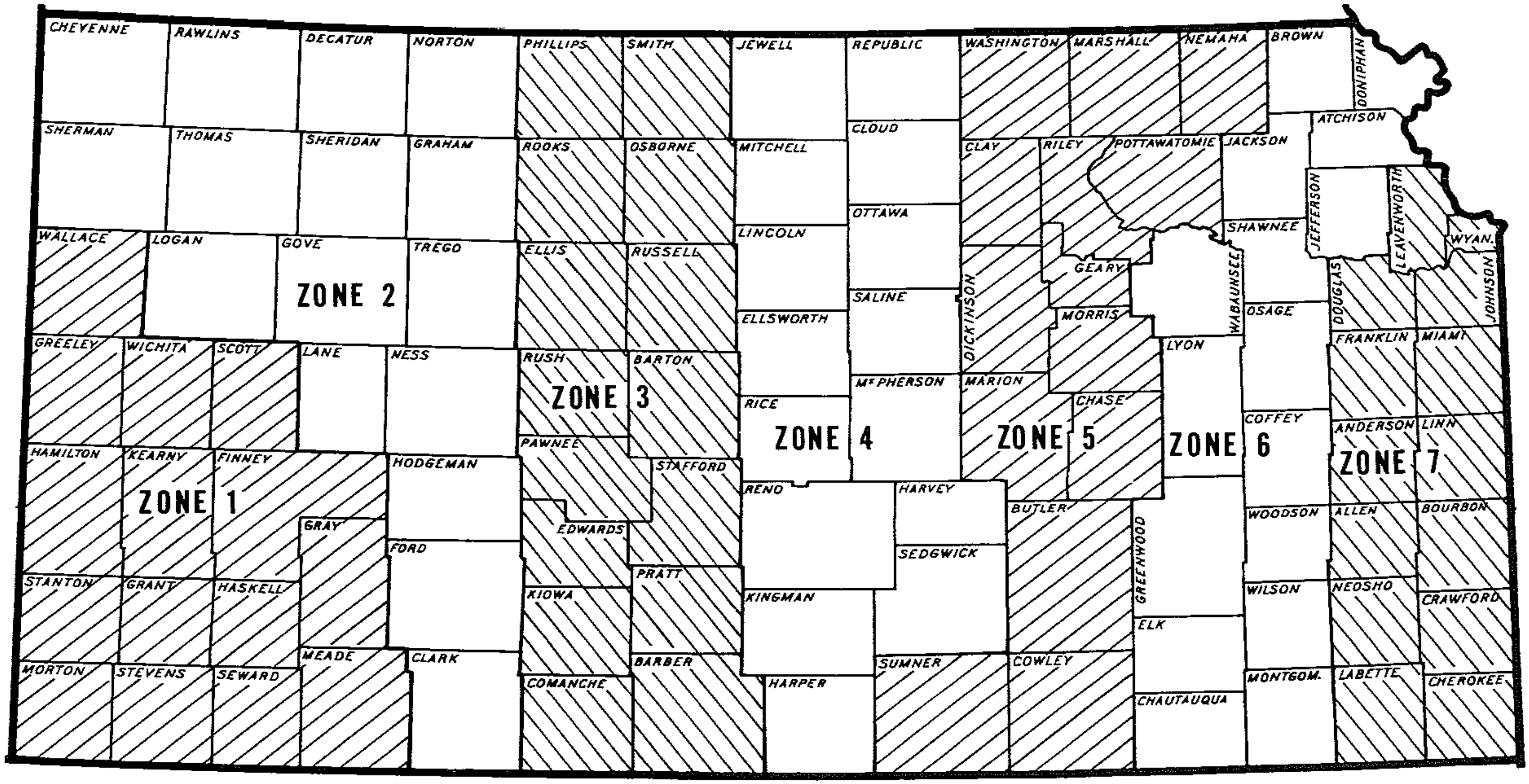


FIG 2-8

which can be expected to be equaled or exceeded 5 years out of 10. Therefore irrigation requirements based on the 80 percent chance rainfall are higher as shown by comparison of values in Table 2.1 against those in Table 2.2. Irrigation based on 80 percent chance rainfall is safer and less risky of drought for the crop than if based on average years. The 80 percent chance rainfall is normally used to determine crop irrigation requirements.

The irrigation requirement values agreed upon by the several agencies involved were the seasonal GIR values in Figures 2-1 through 2-7 and the corresponding seasonal NIR values in Table 2.1.

2. Monthly NIR Values - A trial was made on grouping certain counties together into irrigation zones as shown in Figure 2-8 and a composite NIR analysis by months was made for each zone for each crop. But after due study, it was determined that seasonal NIR values by individual counties would better serve the irrigation need in Kansas, so seasonal NIR by zones was not used. The composite zone analyses, however, did give NIR values by months for the various crops. So monthly NIR values for a crop in any county can be computed by proportioning according to the zone composite for that crop and the zone in which the county is located.

Table 2.3 gives the monthly NIR distribution by percentage as based on the 80 percent chance rainfall. Table 2.4 gives similar monthly NIR distribution by percentage but based on the 50 percent chance rainfall.

Computations of monthly NIR for any of the selected crops for any county can be made as follows:

Example #1 -

What is the monthly net irrigation requirements for alfalfa in Scott County on the 80 percent chance rainfall?

Scott County is in Zone 1 (Figure 2-8).

Scott County seasonal NIR for alfalfa is 25.2 inches (Table 2.1).

Month	% of Seasonal NIR Table 2.3		Monthly NIR	NIR Reduced To Tenths	Adjusted Monthly NIR
April	6.5	.065 x 25.2 =	1.64"	1.6"	1.6"
May	11.5	.115 x 25.2 =	2.90"	2.9"	2.9"
June	18.5	.185 x 25.2 =	4.66"	4.7"	4.7"
July	23.5	.235 x 25.2 =	5.92"	5.9"	5.9"
August	20.4	.204 x 25.2 =	5.14"	5.1"	5.2"
Sept.	13.5	.135 x 25.2 =	3.40"	3.4"	3.4"
Oct.	6.1	.061 x 25.2 =	1.54"	1.5"	1.5"
Total	100.0			25.1"	25.2"

In reducing to tenths 0.1 inch is lost so one of the months must be adjusted upward 0.1 inch to total 25.2 inches. Note that April, August, and October were all reduced 0.04 inch. The largest of these numbers should be the one adjusted.

Example #2 -

What is the monthly net irrigation requirement for corn in Ford County on the 80 percent chance rainfall?

Ford County is in Zone 2 (Figure 2-8).

Ford County seasonal NIR for corn is 15.7 inches (Table 2.1).

Month	% of Seasonal NIR Table 2.3		Monthly NIR	NIR Reduced To Tenths
May	3.9	.039 x 15.7 =	0.61"	0.6"
June	22.7	.227 x 15.7 =	3.56"	3.6"
July	40.9	.409 x 15.7 =	6.42"	6.4"
August	32.5	.325 x 15.7 =	5.10"	5.1"
Total	100.0			15.7"

The total of the added monthly NIR values to the nearest tenth equals the seasonal value, so no adjustment is needed.

Each field office assisted by the area engineer should compute monthly net irrigation requirement values for the several crops for their county utilizing the forms on pages 2-28 and 2-29 to record the data.

Monthly NIR values are important in irrigation water management in making determinations for pumping hours, irrigation timing and other management elements; however, monthly NIR values can vary. Variation in planting and harvesting dates, length of growing season (crop variety variation), off season irrigation and rainfall distribution for a particular year all impact on irrigation requirements during the cropping season. So while monthly NIR values can be developed for the usual condition, they should be considered subject to some fluctuations.

Monthly NIR values may be used to determine frequency of irrigation.

Table 2.1
Seasonal Net Irrigation Requirements (Inches)
80 Percent Chance Rainfall

County	Alfalfa	Corn	Sorghum	Grass	Wheat	Soybeans	S. Beets
Allen	15.5	9.9	6.7	13.5	4.4	6.1	--
Anderson	14.7	9.4	6.3	12.8	3.9	5.5	--
Atchison	16.6	10.3	7.3	14.8	5.5	6.7	--
Barber	23.3	14.6	12.3	21.2	10.3	11.6	--
Barton	22.7	14.4	11.8	20.8	10.1	11.3	--
Bourbon	15.0	9.6	6.6	12.9	4.0	5.8	--
Brown	17.2	10.6	7.7	15.3	6.0	7.2	--
Butler	18.7	12.0	9.0	16.8	6.8	8.2	--
Chase	17.8	11.4	8.3	15.8	6.4	7.5	--
Chautauqua	17.5	11.4	8.5	15.6	5.7	7.8	--
Cherokee	15.2	9.9	7.0	13.2	3.6	6.3	--
Cheyenne	24.5	15.4	13.3	22.4	11.3	12.7	20.3
Clark	24.9	15.7	13.3	22.7	11.6	12.9	20.3
Clay	19.2	12.2	9.4	17.2	7.6	8.6	--
Cloud	20.3	12.7	10.1	18.3	8.5	9.4	--
Coffey	15.6	9.9	6.8	13.7	4.6	6.0	--
Comanche	24.2	15.1	12.8	22.0	11.0	12.4	--
Cowley	18.8	12.3	9.2	17.0	6.8	8.5	--
Crawford	15.3	9.8	7.0	13.2	3.8	6.2	--
Decatur	23.4	14.8	12.5	21.5	10.7	11.9	19.4
Dickinson	19.2	12.3	9.4	17.2	7.5	8.6	--
Doniphan	16.9	10.3	7.5	15.0	5.6	6.9	--
Douglas	15.7	9.8	6.7	13.8	4.6	6.0	--
Edwards	23.9	15.1	12.7	21.8	10.9	12.2	--
Elk	17.4	11.3	8.4	15.5	5.7	7.6	--
Ellis	23.1	14.6	12.2	21.2	10.3	11.6	--
Ellsworth	21.6	13.7	11.2	19.8	9.4	10.5	--
Finney	25.6	16.3	13.9	23.5	12.3	13.4	21.1
Ford	24.8	15.7	13.3	22.6	11.6	12.8	20.3
Franklin	15.0	9.1	6.3	13.0	4.0	5.5	--
Geary	18.2	11.5	8.7	16.1	6.8	7.9	--
Gove	24.3	15.3	13.1	22.3	11.4	12.5	20.2
Graham	23.3	14.7	12.4	21.3	10.6	11.8	19.3
Grant	26.5	16.7	14.6	24.2	13.0	14.0	21
Gray	25.4	16.1	13.8	23			
Greeley	26.0	16.5	14.3	23			
Greenwood	17.0	11.1	7.9	15			
Hamilton	26.6	16.9	14.6				
Harper	22.0	14.0	11.2				
Harvey	20.2	12.9	9.				
Haskell	26.0	16.4	14.				
Hodgeman	24.5	15.5	13.				
Jackson	17.0	10.5	7.				
Jefferson	16.3	10.1	7.				
Jewell	20.9	13.1	10.				
Johnson	15.5	9.5	6.				
Kearny	26.1	16.6	14.				
Kingman	22.2	14.0	11.				
Kiowa	24.1	15.1	12.				
Labette	15.9	10.3	7.				
Lane	24.8	15.7	13.				

Table 2.1 (Continued)

County	Alfalfa	Corn	Sorghum	Grass	Wheat	Soybeans	S. Beets
Leavenworth	16.1	9.9	6.9	14.1	4.9	6.2	--
Lincoln	21.5	13.6	11.1	19.6	9.2	10.4	--
Linn	14.2	9.0	5.8	12.1	3.6	5.0	--
Logan	25.0	15.8	13.7	22.9	11.8	13.1	20.7
Lyon	16.8	10.5	7.4	14.8	5.4	6.7	--
Marion	19.2	12.2	9.2	17.1	7.3	8.5	--
Marshall	18.3	11.4	8.6	16.3	7.0	7.9	--
McPherson	20.7	13.1	10.4	18.8	8.5	9.8	--
Meade	25.5	16.1	13.8	23.4	12.2	13.3	20.9
Miami	14.6	9.0	6.0	12.3	3.7	5.2	--
Mitchell	21.3	13.3	10.9	19.4	9.2	10.2	--
Montgomery	16.7	10.9	8.0	14.6	4.9	7.3	--
Morris	17.9	11.4	8.5	15.9	6.5	7.7	--
Morton	27.3	17.1	15.0	24.8	13.7	14.4	22.2
Nemaha	17.6	10.9	8.1	15.7	6.4	7.5	--
Neosho	15.9	10.2	7.3	13.8	4.5	6.6	--
Ness	24.2	15.3	13.0	22.1	11.2	12.4	20.0
Norton	22.8	14.4	12.1	21.0	10.3	11.5	19.0
Osage	15.9	9.9	6.9	14.0	4.9	6.2	--
Osborne	22.0	13.8	11.4	20.2	9.7	10.8	--
Ottawa	20.5	12.9	10.3	18.5	8.5	9.6	--
Pawnee	23.6	14.9	12.5	21.6	10.7	12.0	--
Phillips	22.2	14.0	11.6	20.5	9.9	11.1	--
Pottawatomie	17.7	11.1	8.3	15.7	6.5	7.5	--
Pratt	23.3	14.6	12.2	21.2	10.3	11.6	--
Rawlins	24.0	15.1	12.9	21.9	11.1	12.4	19.9
Reno	21.8	13.8	11.1	19.8	9.2	10.4	--
Republic	20.0	12.6	9.9	18.1	8.3	9.2	--
Rice	21.9	13.8	11.2	20.0	9.4	10.6	--
Riley	18.2	11.4	8.7	16.2	6.8	8.0	--
Rooks	22.6	14.3	12.0	20.8	10.1	11.3	--
Rush	23.5	14.8	12.4	21.5	10.7	11.9	--
Russell	22.2	14.1	11.6	20.5	9.9	11.1	--
Saline	20.7	13.1	10.5	18.7	8.6	9.6	--
Scott	25.2	15.9	13.8	23.1	12.0	13.2	20.8
Sedgwick	20.3	13.1	10.1	18.4	8.1	9.3	--
Seward	26.1	16.4	14.2	23.9	12.7	13.7	21.3
Shawnee	16.4	10.2	7.3	14.6	5.4	6.6	--
Sheridan	23.9	15.0	12.8	21.8	11.0	12.2	19.8
Sherman	25.0	15.7	13.7	22.9	11.8	13.1	20.7
Smith	21.6	13.6	11.2	19.9	9.5	10.5	--
Stafford	22.9	14.5	12.0	21.0	10.2	11.5	--
Stanton	27.2	17.2	15.0	24.9	13.5	14.4	22.2
Stevens	26.7	16.8	14.6	24.4	13.1	14.0	21.7
Sumner	20.4	13.2	10.2	18.5	8.1	9.4	--
Thomas	24.4	15.4	13.3	22.3	11.4	12.7	20.1
Trego	23.7	15.0	12.7	21.7	10.9	12.1	19.6
Wabaunsee	17.0	10.7	7.8	15.2	5.9	7.1	--
Wallace	25.5	16.1	14.0	23.3	12.2	13.5	21.1
Washington	19.1	12.0	9.3	17.2	7.7	8.6	--
Wichita	25.6	16.3	14.0	23.5	12.3	13.5	21.1
Wilson	16.4	10.7	7.7	14.5	5.1	6.9	--
Woodson	16.1	10.4	7.3	14.2	4.9	6.5	--
Wyandotte	15.8	9.8	6.7	13.8	4.6	6.0	--

Table 2.2
Seasonal Net Irrigation Requirements (Inches)
50 Percent Chance Rainfall

County	Alfalfa	Corn	Sorghum	Grass	Wheat	Soybeans	S. Beets
Allen	10.8	7.1	4.1	8.8	1.3	3.0	--
Anderson	9.2	6.1	3.1	7.3	0.2	1.8	--
Atchison	11.9	7.2	4.5	10.0	2.1	3.4	--
Barber	20.1	12.6	10.5	18.0	8.1	9.6	--
Barton	19.3	12.0	9.7	17.4	7.8	8.9	--
Bourbon	10.3	6.8	4.1	8.2	0.4	2.9	--
Brown	11.6	7.1	4.1	9.7	1.6	2.9	--
Butler	14.2	9.2	6.3	12.0	3.8	5.2	--
Chase	13.4	8.7	5.7	11.4	3.6	4.6	--
Chautauqua	12.7	8.6	6.0	10.8	1.8	4.8	--
Cherokee	10.2	7.0	4.3	8.2	0.0	3.1	--
Cheyenne	22.1	13.7	12.0	20.0	9.6	11.2	17.8
Clark	22.0	13.7	11.7	19.8	9.7	10.8	17.3
Clay	15.0	9.2	6.7	12.9	4.5	5.6	--
Cloud	16.7	10.3	8.0	14.8	5.9	7.0	--
Coffey	10.4	6.8	3.7	8.4	0.4	2.4	--
Comanche	21.0	13.0	10.9	18.8	8.8	10.1	--
Cowley	14.6	9.7	6.8	12.8	4.0	5.7	--
Crawford	10.5	7.0	4.5	8.4	0.0	3.2	--
Decatur	20.5	12.7	10.7	18.5	8.7	9.8	16.3
Dickinson	14.9	9.4	6.9	12.9	4.5	5.8	--
Doniphan	12.3	7.3	4.8	10.3	2.3	3.8	--
Douglas	11.1	6.8	4.1	9.2	1.2	3.1	--
Edwards	20.9	13.0	11.0	18.8	8.7	10.2	--
Elk	12.9	8.7	5.8	10.9	2.5	4.7	--
Ellis	19.8	12.2	10.2	17.9	8.1	9.2	--
Ellsworth	18.1	11.5	9.0	16.2	6.9	8.1	--
Finney	23.1	14.5	12.4	21.0	10.6	11.7	18.5
Ford	21.8	13.7	11.6	19.7	9.5	10.8	17.3
Franklin	9.7	5.8	3.2	7.8	0.5	2.0	--
Geary	13.5	8.4	6.0	11.4	3.3	4.8	--
Gove	21.3	13.1	11.2	19.3	9.2	10.4	17.0
Graham	20.7	12.4	10.5	18.4	8.3	9.6	16.0
Grant	24.0	14.9	13.1	21.8	11.3	12.3	19.2
Gray	22.3	13.8	11.8	20.0	9.9	11.0	17.4
Greeley	23.6	14.7	12.9	21.5	11.0	12.1	19.0
Greenwood	12.3	8.1	5.1	10.3	2.0	3.9	--
Hamilton	24.2	15.2	13.2	22.1	11.6	12.5	19.4
Harper	18.5	11.7	9.3	16.5	6.5	8.3	--
Harvey	15.8	10.2	7.2	13.8	5.0	6.1	--
Haskell	23.3	14.5	12.6	21.2	10.8	11.8	18.5
Hodgeman	21.6	13.4	11.5	19.5	9.4	10.7	17.2
Jackson	12.3	7.4	4.7	10.4	2.4	3.7	--
Jefferson	11.5	7.0	4.2	9.7	2.0	3.2	--
Jewell	17.3	10.6	8.3	15.4	6.5	7.3	--
Johnson	11.5	6.6	3.7	9.4	0.7	2.6	--
Kearny	23.8	14.9	12.9	21.7	11.2	12.1	19.0
Kingman	18.5	11.7	9.2	16.4	6.8	8.2	--
Kiowa	21.1	13.2	11.2	19.1	8.8	10.4	--
Labette	10.7	7.3	4.8	8.7	0.4	3.5	--
Lane	21.9	13.7	11.7	19.8	9.8	10.9	17.6

Table 2.2 (Continued)

County	Alfalfa	Corn	Sorghum	Grass	Wheat	Soybeans	S. Beets
Leavenworth	11.5	7.0	4.3	9.5	1.6	3.3	--
Lincoln	17.9	11.3	8.9	16.0	6.9	7.9	--
Linn	8.7	5.6	2.6	6.4	0.0	1.4	--
Logan	22.4	13.9	12.1	20.3	10.1	11.3	18.0
Lyon	11.4	7.5	4.4	9.9	2.0	3.4	--
Marion	14.9	9.6	6.4	12.8	4.5	5.5	--
Marshall	14.2	8.7	6.1	12.3	4.3	5.0	--
McPherson	17.0	10.8	8.3	15.1	5.9	7.3	--
Meade	22.8	14.3	12.2	20.7	10.2	11.4	18.1
Miami	9.2	5.0	3.0	7.1	0.0	1.8	--
Mitchell	17.7	10.8	8.8	15.9	6.7	7.8	--
Montgomery	12.1	8.1	5.5	10.0	1.2	4.3	--
Morris	13.4	8.5	5.9	11.4	3.3	4.7	--
Morton	24.9	15.4	13.5	22.5	12.1	12.7	19.8
Nemaha	12.9	7.8	5.3	11.0	3.2	4.6	--
Neosho	10.8	7.1	4.5	8.7	0.5	3.2	--
Ness	20.5	13.3	11.3	19.3	9.3	10.4	17.1
Norton	19.8	12.3	10.3	18.0	8.3	9.4	15.9
Osage	11.2	7.0	4.2	9.4	1.8	3.2	--
Osborne	18.8	11.7	9.5	17.0	7.5	8.6	--
Ottawa	16.7	10.5	8.0	14.7	6.0	6.7	--
Pawnee	20.5	12.7	10.6	18.5	8.6	9.7	--
Phillips	19.0	11.7	9.7	17.3	7.8	8.8	--
Pottawatomie	13.4	8.1	5.6	11.5	3.5	4.6	--
Pratt	20.2	12.6	10.5	18.1	8.0	9.6	--
Rawlins	21.2	13.2	11.3	19.1	9.1	10.5	17.5
Reno	18.1	11.4	8.9	16.1	6.6	7.9	--
Republic	16.1	10.0	7.4	14.2	5.7	6.4	--
Rice	18.4	11.5	9.1	16.5	7.0	8.2	--
Riley	13.7	8.5	6.0	11.7	3.8	4.9	--
Rooks	19.5	12.0	10.0	17.6	7.9	9.1	--
Rush	20.3	12.6	10.4	18.3	8.5	9.6	--
Russell	18.6	11.3	9.4	16.9	7.5	8.5	--
Saline	17.1	10.8	8.3	15.1	6.1	7.3	--
Scott	22.5	14.0	12.2	20.5	10.1	11.3	18.1
Sedgwick	16.3	10.7	7.7	14.4	5.4	6.6	--
Seward	23.5	14.5	12.8	21.3	10.9	11.9	18.7
Shawnee	12.2	7.4	4.9	10.4	2.4	4.0	--
Sheridan	21.0	12.9	11.0	19.0	9.1	10.2	17.3
Sherman	22.8	14.1	12.3	20.7	10.4	11.6	18.4
Smith	18.4	11.4	9.2	16.6	7.3	8.2	--
Stafford	19.7	12.3	10.2	17.7	7.8	9.3	--
Stanton	25.0	15.6	13.7	22.7	12.1	12.9	20.0
Stevens	23.9	14.8	12.9	21.7	11.4	12.1	18.9
Sumner	15.9	10.3	7.4	13.8	4.8	6.3	--
Thomas	21.9	13.5	11.7	19.7	9.6	10.9	17.6
Trego	20.8	12.9	11.0	18.8	8.8	10.1	16.7
Wabaunsee	12.3	7.8	5.0	10.5	2.5	3.9	--
Wallace	23.0	14.3	12.5	20.8	10.4	11.8	18.5
Washington	15.1	9.2	6.8	13.1	5.0	5.7	--
Wichita	23.1	14.4	12.5	21.0	10.5	11.8	18.5
Wilson	12.0	8.0	5.1	10.1	1.9	3.9	--
Woodson	11.3	7.4	4.5	9.4	1.4	3.3	--
Wyandotte	11.1	7.0	4.1	9.2	1.3	3.1	--

Table 2.3

Monthly Distribution of Net Irrigation Requirements
in Percent of Seasonal Total
Based on 80 Percent Chance Rainfall

Zone	April	May	June	July	Aug.	Sept.	Oct.	Total
ALFALFA								
1	6.5	11.5	18.5	23.5	20.4	13.5	6.1	100
2	6.1	11.3	18.2	24.3	21.0	13.0	6.1	100
3	5.1	12.7	17.8	24.6	21.6	13.1	5.1	100
4	3.7	11.6	19.1	26.5	23.3	12.1	3.7	100
5	1.6	12.2	19.2	28.2	25.0	12.2	1.6	100
6	--	11.7	19.9	30.4	26.3	11.7	--	100
7	--	10.3	21.1	31.4	28.2	9.0	--	100
CORN								
1	--	6.7	23.6	38.2	31.5	--	--	100
2	--	3.9	22.7	40.9	32.5	--	--	100
3	--	1.4	22.9	43.1	32.6	--	--	100
4	--	--	21.8	45.1	33.1	--	--	100
5	--	--	19.0	49.1	31.9	--	--	100
6	--	--	15.3	53.3	31.4	--	--	100
7	--	--	14.2	54.5	31.3	--	--	100
SORGHUM								
1	--	--	8.4	38.4	36.4	16.8	--	100
2	--	--	4.6	42.0	38.9	14.5	--	100
3	--	--	1.7	44.6	41.3	12.4	--	100
4	--	--	--	45.8	46.7	7.5	--	100
5	--	--	--	46.7	51.1	2.2	--	100
6	--	--	--	46.8	53.2	--	--	100
7	--	--	--	44.1	55.9	--	--	100

Table 2.3 (Continued)

Zone	April	May	June	July	Aug.	Sept.	Oct.	Total
TAME GRASS								
1	6.7	11.3	17.9	22.9	20.8	14.2	6.2	100
2	6.1	11.0	17.6	23.7	21.5	14.0	6.1	100
3	5.1	12.5	16.7	24.1	22.2	13.9	5.5	100
4	3.6	11.8	17.9	26.2	24.6	12.3	3.6	100
5	1.2	12.3	17.5	28.1	25.7	12.9	2.3	100
6	--	11.2	18.4	30.9	27.6	11.9	--	100
7	--	8.0	19.7	32.1	30.7	9.5	--	100
SOYBEANS								
1	--	--	5.6	22.9	45.1	26.4	--	100
2	--	--	1.6	24.6	49.2	24.6	--	100
3	--	--	--	24.4	52.0	23.6	--	100
4	--	--	--	20.6	58.8	20.6	--	100
5	--	--	--	20.6	62.0	17.4	--	100
6	--	--	--	21.0	64.2	14.8	--	100
7	--	--	--	18.1	70.8	11.1	--	100
SUGAR BEETS								
1	9.3*	--	10.8	26.2	28.5	19.6	5.6	100
2	10.0*	--	8.0	28.0	30.0	19.5	4.5	100
Zone	Oct.	Nov.	--	Mar.	Apr.	May	--	Total
WHEAT								
1	12.6	10.2	--	15.3	26.3	35.6	--	100
2	11.7	10.0	--	13.3	28.3	36.7	--	100
3	8.2	10.9	--	13.6	30.0	37.3	--	100
4	5.4	13.1	--	14.1	33.7	33.7	--	100
5	--	13.2	--	11.8	38.2	36.8	--	100
6	--	5.0	--	13.3	41.7	40.0	--	100
7	--	--	--	14.6	43.7	41.7	--	100

*Net irrigation of 2" for germination

Table 2.4

Monthly Distribution of Net Irrigation Requirements
in Percent of Seasonal Total
Based on 50 Percent Chance Rainfall

Page 1 of 2

Zone	April	May	June	July	Aug.	Sept.	Oct.	Total
ALFALFA								
1	6.1	10.9	18.3	23.6	21.0	14.0	6.1	100
2	5.6	10.7	17.7	24.8	22.0	13.1	6.1	100
3	4.4	12.3	17.3	25.6	22.2	13.3	4.9	100
4	2.8	11.3	18.4	27.9	25.1	11.7	2.8	100
5	--	11.3	18.7	30.7	27.3	12.0	--	100
6	--	7.6	19.8	34.4	29.8	8.4	--	100
7	--	4.3	21.6	36.2	33.6	4.3	--	100
CORN								
1	--	4.3	23.4	39.7	32.6	--	--	100
2	--	1.5	21.5	43.1	33.9	--	--	100
3	--	--	19.8	46.3	33.9	--	--	100
4	--	--	15.6	49.5	34.9	--	--	100
5	--	--	9.9	54.9	35.2	--	--	100
6	--	--	5.0	61.2	33.8	--	--	100
7	--	--	4.0	62.7	33.3	--	--	100
SORGHUM								
1	--	--	4.9	39.8	37.4	17.9	--	100
2	--	--	1.0	43.6	40.9	14.5	--	100
3	--	--	--	44.0	45.0	11.0	--	100
4	--	--	--	44.7	51.8	3.5	--	100
5	--	--	--	45.7	54.3	--	--	100
6	--	--	--	48.3	51.7	--	--	100
7	--	--	--	47.0	53.0	--	--	100

Table 2.4 (Continued)

April	May	June	July	Aug.	Sept.	Oct.	Total
TAME GRASS							
6.2	10.5	17.2	23.5	21.5	14.9	6.2	100
5.6	10.2	16.8	24.5	22.5	14.3	6.1	100
4.3	12.0	16.3	25.0	23.4	14.1	4.9	100
2.5	10.6	17.5	28.1	26.9	11.9	2.5	100
--	10.5	17.3	30.8	28.6	12.8	--	100
--	5.3	17.7	35.4	32.7	8.9	--	100
--	1.0	20.4	38.8	36.7	3.1	--	100
SOYBEANS							
--	--	1.6	22.1	48.4	27.9	--	100
--	--	--	21.6	52.3	26.1	--	100
--	--	--	21.7	54.7	23.6	--	100
--	--	--	17.8	63.3	18.9	--	100
--	--	--	17.6	67.6	14.8	--	100
--	--	--	18.7	71.9	9.4	--	100
--	--	--	14.6	81.8	3.6	--	100
SUGAR BEETS							
10.6*	--	6.9	26.6	29.3	20.8	5.8	100
11.6*	--	2.3	29.1	31.4	20.9	4.7	100
Oct.	Nov.	--	Mar.	Apr.	May	--	Total
WHEAT							
9.3	10.2	--	16.1	28.0	36.4	--	100
7.0	11.0	--	13.0	31.0	38.0	--	100
6.6	12.1	--	14.3	33.0	34.0	--	100
4.0	13.1	--	13.1	35.6	34.2	--	100
--	10.3	--	12.1	41.4	36.2	--	100
--	--	--	9.8	51.2	39.0	--	100
--	--	--	--	60.0	40.0	--	100

irrigation of 2" for germination

Example -

What is the frequency of irrigation needed for corn in Ford County during the month of July, based on 80 percent chance rainfall, where the net irrigation application is 3 inches?

From the previous example, NIR for corn in July in Ford County is 6.4 inches.

Average July NIR is 6.4 inches.

Average daily NIR is 6.4 ÷ 31 days = .206"/day

$$\frac{\text{Net Irrig. Appl. (inches)}}{\text{Avg. Crop Daily Use ("/day)}} = \text{Avg. Irrig. Frequency (days)}$$

or $$\frac{3\text{" Appl.}}{.206\text{"/day}} = 14.5 \text{ days (use 14)}$$

This irrigation frequency represents the July period irrigation need but does not represent the irrigation frequency related to peak consumptive use rate of the crop.

C. Peak Consumptive Use

The consumptive use (CU) of crops has been calculated by computer program based on criteria outlined in Technical Release 21. There is only minor variation in peak consumptive use across the state for a given crop so only one table on peak consumptive use rate (inches per day) is developed for the state (see Table 2.5).

Example -

Corn crop, Ford County, 3" net application.

Corn with 3" net application has peak CU of .31" per day (Table 2.5).

Irrigation frequency (Table 2.6) $= \frac{3.0\text{"}}{.31\text{"/day}} = 9.7$ days (Use 10)

Peak consumptive use period for corn might be a 7 to 10 day period in late July or early August; however, stage of crop growth and temperature variations can vary the timing and span of the peak use period by several days.

For the peak consumptive use period of corn the irrigation frequency in the example is 10 days (no rainfall considered). But based on general conditions for the July period (with 80% chance rainfall) the irrigation frequency is 14 days (previous

example). This information then should give the irrigator a good basis for judging irrigation frequency to fit the conditions at hand.

Table 2.5

Peak Consumptive Use Rate (Inches/Day)

Crop	Net Irrigation Application (Inches)				
	1.0	2.0	3.0	4.0	5.0
Alfalfa, corn	0.34	0.32	0.31	0.30	0.29
Grass	0.32	0.30	0.29	0.28	0.27
Sorghum, potatoes	0.31	0.29	0.28	0.27	0.26
Sugar beets, beans	0.29	0.28	0.27	0.26	0.25
Small grain	0.23	0.22	0.21	0.20	0.20
Melons	0.28	0.27	0.26	0.25	0.25
Orchard w/cover	0.26	0.25	0.25	0.23	0.23

Table 2.6

Irrigation Frequency During Period of Maximum Consumptive Use (Days)

Crop	Net Irrigation Application (Inches)				
	1.0	2.0	3.0	4.0	5.0
Alfalfa, corn	3	6	10	13	17
Grass	3	7	10	14	18
Sorghum, potatoes	3	7	11	15	19
Sugar beets, beans	3	7	11	15	20
Small grain	4	9	14	20	25
Melons	4	7	12	16	20
Orchard w/cover	4	8	12	17	22

Water Requirement

Irrigated lands should be developed to accommodate a maximum number of irrigation methods adaptable to the area to enhance efficiency and flexibility of the system. Total water requirements will be contingent upon the crops grown, the acres involved, and the system efficiency. The crops should be consistent with good agronomic management and the irrigation system must be designed within limitations imposed by consumptive use (CU) requirements of the planned cropping system.

Example:

A farm near Colby has 320 acres of irrigated cropland. The soil is a Keith silt loam. The water supply is from a well delivering 900 g.p.m. The farm delivery system has an estimated efficiency of 70 percent (see page 1-7). Crops being grown are 30 acres of alfalfa and 60 acres of corn. Full irrigation is planned for these. Each irrigation will consist of a net application of 4 inches for these crops. An additional 70 acres of corn will be irrigated on a selective basis. This will consist of a pre-irrigation of 4 inches net before planting and two 2-inch net applications during the latter part of June and the first part of July prior to silk emergence. In addition, it is planned to pre-irrigate 80 acres of sorghum (5 inches net) in March and winter irrigate (5 inches net) in October. Also, 80 acres of wheat will be irrigated (4-inch net each application) in April and September.

Determine the monthly net irrigation requirements (NIR) for the 30 acres of alfalfa and the 60 acres of corn which are under full irrigation. Base the NIR on 80 percent chance rainfall for Thomas County. Also determine the water requirements for the other corn, sorghum, and wheat for the type of irrigation planned.

Thomas County is in Zone 2 (Fig. 2-8, pg. 2-10). Seasonal NIR for alfalfa is 24.4 inches and 15.4 inches for corn (Table 2.1, pg. 2-14). Compute monthly NIR for alfalfa and corn as follows:

Crop	Apr.	May	June	July	Aug.	Sept.	Oct.	Total
Alfalfa	1.5	2.8	4.4	5.9	5.1	3.2	1.5	24.4 in.
Corn	-	0.6	3.5	6.3	5.0	-	-	15.4 in.

Table 2.7 (Form KS-ENG-394) is used to analyze irrigation water requirements by crop by month and for the total season. It is also used to compute pumping hours to make certain the pumping rate will meet the water needs of the irrigation system as planned.

In Table 2.7, monthly NIR values are in the top block of the form for the crop and month. These computed values are transferred directly to the form.

Net monthly water requirements for full and selective irrigation are recorded in the second block of Table 2.7. For full irrigation they are obtained by multiplying crop acres times monthly NIR values. For example, the water requirement for alfalfa for July is 30 acres x 5.9 inches = 177 acre-inches as shown in Table 2.7; for corn, 60 acres x 6.3 inches = 378 acre-inches. The 70 acres of corn under selective irrigation would receive a 4-inch net application in May or 70 acres x 4.0 inches = 280 acre-inches.

Likewise, for the pre-irrigation of sorghum in March, 80 acres x 5.0 inches = 400 acre-inches. This would be entered in the third block in Table 2.7.

Table 2.7

KS-ENG-394
Rev. 2/82

Operator: Example

Address:

Location:

IRRIGATION WATER MANAGEMENT
CROPS AND WATER REQUIREMENT
SUMMARY FOR WATER YEAR ____

Well Discharge or Water Delivery 900 g.p.m.

Conservation Plan No: ____

Thomas County SCS No: ____

Date: ____

CROP	* Net Monthly Water Requirement - Acre Inches Per Acre											
	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG.	SEPT	OCT	NOV.	DEC.
Alfalfa				1.5	2.8	4.4	5.9	5.1	3.2	1.5		
Corn					0.6	3.5	6.3	5.0				
Sorghum												
Sugar Beets												
Soybeans												
Wheat												
Grass												

FIELD NO	ACRES	CROP	Net Monthly Water Requirement - Acre Inches Per Crop											
			JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
			Area for Crops Receiving Full or Selected Irrigation During the Summer											
1	30	Alfalfa				45	84	132	177	153	96	45		
2	60	Corn					36	210	378	300				
3	70	Corn (selected irrigation)					280	140	140					
SUB-TOTAL						45	400	482	695	453	96	45		
			Area for Crops Receiving Pre-irrigation and/or Fall & Winter Irrigation											
4	80	Sorghum			400							400		
5	80	Wheat				320					320			
SUB-TOTAL					400	320								
GRAND TOTAL					400	365	400	482	695	453	416	445		
Pumping Hours (0.70 Eff)					286	261	286	344	496	324	297	318		

Pumping Hours = $\frac{450 \times \text{Total Acre Inches}}{\text{gpm} \times \text{Eff (Decimal)}}$

* Net Monthly Water Requirement Acre Inches Per Acre (From Part 2 Irrigation Guide 80% Chance)

Maximum Condition: 20 hr. pumping day = $\frac{900}{450} \times 20 \times 0.7 = 28$ Ac.In. $\times$ 25 days = 700 Ac.In.

PEAK PERIOD CONSUMPTIVE USE RATE - Inches Per Day

CROP	Net Irrigation Application 1"	2"	3"	4"	5"	CROP	Net Irrigation Application 1"	2"	3"	4"	5"
Alfalfa, Corn	0.34	0.32	0.31	0.30	0.29	Grass	0.32	0.30	0.29	0.28	0.27
Sorghum	0.31	0.29	0.28	0.27	0.26	Small Grain	0.23	0.22	0.21	0.20	0.20
Sugar Beets, Beans	0.29	0.28	0.27	0.26	0.25						

The winter months will and can be utilized more than is shown on this example if necessary. Total net water requirements by months are shown on the grand total line. Pumping hours can be determined by the use of the formula shown near the bottom of the form.

Note from Table 2.7 that the greatest net monthly demand is 695 acre-inches in July.

$$\text{Maximum pumping hours} = \frac{450 \times 695}{900 \times 0.70} = 496 \text{ hours}$$

With a pumping time of 20 hours per day, it would take 25 days of pumping to meet the July water requirements.

The following analysis for the same farm relates to periods of peak consumptive use (CU) and without rainfall which is the most demanding water requirement condition.

For a 4-inch net application, both alfalfa and corn have a peak consumptive use of 0.30 inch per day. (Table 2.5, page 2-22)

$$\text{Irrigation frequency for peak CU} = \frac{4.0}{0.30} = 14 \text{ days}$$

$$\text{Average gross application (water pumped)} = \frac{4.0}{0.70} = 5.71 \text{ in./ac.}$$

Total gross water required = 90 ac. x 5.71 in. = 514 Ac. In.

Well discharge = 900 g.p.m. = 2.0 c.f.s. = 2.0 Ac. In./Hr.

$$\text{Gross pumping time} = \frac{514 \text{ Ac. In.}}{2.0 \text{ Ac. In./Hr.}} = 257 \text{ hours}$$

$$\frac{257 \text{ hrs.}}{14 \text{ days}} = 18.4 \text{ hr. pumping day during peak CU}$$

The alfalfa and corn under full irrigation would be adequately taken care of. However, depending on when the peak use period occurs, the 70 acres of corn being selectively irrigated could be adversely affected. During a 14-day period of peak CU it would only be possible to apply the following water with 24-hour pumping days:

$$\begin{aligned}(24 \text{ hrs.} - 18.4 \text{ hrs.}) &= 5.6 \text{ hours/day of pumping time} \times 14 \\ &= 78.4 \text{ hrs.} \times 2.0 \text{ Ac. In./hr.} = 157 \text{ Ac. In. gross} \\ &= 157 \times 0.70 = 110 \text{ Ac. In. net} \\ \text{or } \frac{110}{70 \text{ Ac.}} &= 1.6 \text{ in. available water}\end{aligned}$$

E. Critical Growth Period and Moisture Stress

To produce maximum crop yields plants must have ample moisture throughout the growing season. Some irrigators, however, may elect to use selective irrigations at critical crop growth periods rather than full irrigation. In some cases they have more land available for irrigation than they have water so it is more economically feasible to use selective irrigation. The additional acres, while yielding less than if fully irrigated, still return more in overall yields than a smaller area under full irrigation.

Regardless of what system of irrigation is being used, plants indicate moisture stress by various symptons. Usually yields will be reduced (depending on the severity and duration of the moisture stress) by the time the plant shows it. Time of irrigation should be determined by examination of the soil for moisture content. Also, under selective irrigation, the irrigator must be aware of what crop growth stage the plant is in. The feel and appearance of the soil at various moisture content are given in part 8 of this guide. Symptons of serious moisture stress, critical water requirement periods, and other irrigation considerations are listed in Table 2.8, page 2-27.

Table 2.8

Moisture Stress Symptoms and Critical Growth Period for Irrigated Crops

Crop	Serious Moisture Stress	Critical Growth Period	Other Considerations
Alfalfa	Bluish green color, then wilting.	Seedling and immediately after cuttings.	Soil kept moist in upper 5 ft. Avoid over-irrigation. Fall irrigation is desirable.
Corn	Leaf curl by 10:00 a.m.	Tasseling; silk stage until grain becomes firm.	Sensitive to over-irrigation. Needs adequate moisture from germination to dent stage.
Sorghum	Leaf curl by 10:00 a.m.	Boot, bloom, and milk-dough stages.	Need adequate moisture--germination through dough stage. Reduced yields when moisture is short during heading and seed development.
Grass Pasture	Dull green color, then wilting.	Seedling stage, for seed production boot to head formation.	Late fall irrigation is necessary. Frequent, light applications. Irrigate at end of grazing period in a rotation system.
Sugar Beets	Leaves wilting during mid-day.	From seedling stage through root enlargement.	Shallow, frequent irrigation. Avoid over-irrigation. Late fall irrigation lowers amount of sugar.
Small Grain	Dull green color, then firing of lower leaves.	Boot, bloom and early head stage.	Fall grain, irrigate before planting to top 4 ft. Last irrigation at milk stage. Spring small grain as a nurse crop, irrigate for needs of grass seedlings.
Dry Beans & Soybeans	Dull color, then wilting.	Early bloom, seed forming.	Very sensitive to over-irrigation. Last irrigation at time of first set of pod maturity.

______________ County

Net Irrigation Requirements (Inches)

For Rainfall 8 Years Out of 10 (80% Chance - Dry Years)

Crop / Month	Alfalfa	Corn	Sorghum	Grass	Wheat	Soybeans	Sugar Beets
March							
April							
May							
June							
July							
August							
Sept.							
Oct.							
Nov.							
Total*							

*From Table 2.1

______________ County

Net Irrigation Requirements (Inches)

For Rainfall 5 Years Out of 10 (50% Chance - Normal Years)

Crop / Month	Alfalfa	Corn	Sorghum	Grass	Wheat	Soybeans	Sugar Beets
March							
April							
May							
June							
July							
August							
Sept.							
Oct.							
Nov.							
Total*							

*From Table 2.2

PART 3 - SOILS

General Information

The soils listed in this irrigation guide include all the irrigable soils presently being mapped in Kansas. Land types and soils generally considered non-irrigable are not included. As additional soils are recognized, they are to be added to the appropriate irrigation design group.

The soils in each series were evaluated and placed into one of 12 groups called irrigation design groups. Soils having approximately equal intake rates, available water capacities, and available root zone depths were placed together. Some groups include soils with minor variations in intake rate, available water capacity and permeability.

The grouping of soils is shown in the two listings that follow. The first list shows all the soils in alphabetical order by series with dominant surface texture with the appropriate irrigation design group. Soils with similar surface textures to those listed are to be considered in the same irrigation design group. The second listing is by irrigation design groups and gives the principal soils included in each of the 12 groups. The intake family used in preparing the design data is included.

Included is a general description of the texture profiles for each design group. The estimated available water capacity for each soil group follows the description. The amounts of moisture are cumulative by one foot or one-half foot increments of depth.

The most common soils are listed below the available water capacities for each design group.

A form for listing each soil and the irrigation design group number in a county or survey area is included last in this section. Listing the mapping unit or soils in a county on one or several pages of this form simplifies the use of this guide for each county.

The state-wide list that follows this section will be of value in preparing the county list. For irrigable soils not listed in the guide or for soils with substantial texture or profile variation from that listed in the guide consult with appropriate SCS soil scientists to properly list these variant soils in the correct irrigation group.

SERIES	IRRIGATION DESIGN GROUP
Albion sandy loam	10
Angelus silt loam	5
Anselmo fine sandy loam	9
Armo loam	5
Attica fine sandy loam 1/	9
Bates loam	8
Bayard fine sandy loam	9
Bethany silt loam	3
Bippus clay loam	5
Blanket silt loam	3
Boel fine sandy loam	12
Bowdoin clay loam 2/	2
Bremer silty clay loam	3
Brewer silty clay loam	3
Bridgeport silt loam	5
Burchard clay loam	5
Butler silt loam	1
Campus loam	6
Canadian fine sandy loam	9
Carlson silt loam	3
Carr fine sandy loam	9
Caruso loam	5
Carwile fine sandy loam	3
Case clay loam	5
Cass fine sandy loam	9
Catoosa silt loam	6
Chase silty clay loam	3
Cherokee silt loam	1
Church silty clay loam	3
Clairemont silt loam	5
Clark clay loam	5
Cleora fine sandy loam	7
Colby silt loam	5
Coly silt loam	5
Corbin silt loam	5
Corinth silty clay loam	4
Cozad silt loam	5
Crete silt loam	3
Crisfield fine sandy loam	9
Dale clay loam	5
Dalhart fine sandy loam 3/	7

SERIES	IRRIGATION DESIGN GROUP
Dennis silt loam.	3
Detroit silty clay loam	3
Dillwyn loamy fine sand	12
Drummond silt loam 4/	3
Dwyer loamy fine sand	12
Elkader silt loam	5
Elmont silt loam.	5
Elsmere loamy fine sand	12
Eltree silt loam.	5
Eudora silt loam.	7
Farnum loam	5
Geary silt loam	5
Gerlane fine sandy loam	9
Girard silty clay loam.	4
Glenberg fine sandy loam.	9
Goessel silty clay.	2
Goshen silt loam.	5
Grant silt loam	5
Grigston silt loam.	5
Grundy silty clay loam.	1
Gymer silt loam	3
Haig silty clay loam.	1
Hall silt loam.	5
Harney silt loam.	3
Hastings silt loam.	3
Haynie silt loam.	7
Hepler silt loam.	5
Hobbs silt loam	5
Holdrege silt loam.	5
Hord silt loam.	5
Humbarger loam.	5
Inavale loamy sand.	12
Irwin silty clay loam	1
Ivan silt loam.	5
Judson silt loam.	5
Kahola silt loam.	5
Kaski loam	5

SERIES	IRRIGATION DESIGN GROUP
Keith silt loam	5
Kenesaw silt loam	7
Kennebec silt loam	5
Kenoma silt loam	1
Kim clay loam	5
Kimo silty clay loam	3
Kingfisher silt loam	6
Kirkland silt loam	1
Konawa fine sandy loam	7
Labette silty clay loam	4
Ladysmith silty clay loam	1
Lancaster loam	8
Lanton silty clay loam	3
Las clay loam	4
Las Animas sandy loam	10
Leanna silt loam	1
Leshara clay loam	5
Lesho clay loam	4
Likes loamy sand	12
Lincoln sand	12
Lockhard silt loam	1
Lofton silty clay loam	1
Longford silt loam	1
Lubbock silty clay loam	3
Lula silt loam	5
Mangum clay	2
Mansic clay loam	5
Mansker clay loam	6
Manter fine sandy loam	7
Manvel silt loam	5
Marshall silt loam	5
Martin silty clay loam	3
Mason silt loam	5
Mayes silty clay loam	1
McCook silt loam	7
McCune silt loam	5
Mento silt loam	3
Milan loam	5
Minco silt loam	7
Minnequa silt loam	5
Missler silty clay loam	3
Monona silt loam	5

SERIES	IRRIGATION DESIGN GROUP
Morrill loam	5
Muir silt loam	5
Munjor sandy loam	9
Naron fine sandy loam	7
Nash loam	8
Nashville silt loam	8
Ness silty clay	2
New Cambria silty clay	2
Norge silt loam	5
Nuckolls silt loam	5
Okemah silt loam	3
Onawa silty clay loam	2
Ortello fine sandy loam	9
Osage silty clay	2
Oska silty clay loam	4
Ost clay loam	5
Otero fine sandy loam	9
Parsons silt loam	1
Pawnee clay loam	1
Penden clay loam	5
Platte loam	12
Pleasant silty clay loam	1
Plevna fine sandy loam	9
Pond Creek silt loam	5
Port silt loam	5
Pratt loamy fine sand	11
Promise clay	2
Radley silt loam	5
Randall clay	2
Reading silt loam	5
Reinach silt loam	7
Renfrow clay loam	1
Richfield silt loam 5/	3
Roxbury silt loam	5
Ruella loam	5
Ryus silty clay loam	3
Sarpy loamy fine sand	12
Satanta loam	5
Sharpsburg silty clay loam	3

SERIES	IRRIGATION DESIGN GROUP
Shelby loam	5
Shellabarger fine sandy loam 3/	7
Sibleyville loam	8
Smolan silty clay loam	1
Solomon silty clay	2
Spearville silty clay loam	1
Stephenville fine sandy loam	8
Summit silty clay loam	3
Sutphen silty clay	2
Tabler clay loam	1
Thurman loamy fine sand	12
Tivoli fine sand	12
Tobin silt loam	5
Tully silty clay loam	3
Uly silt loam	5
Ulysses silt loam	5
Vanoss silt loam	5
Verdigris silt loam	5
Vona loamy fine sand	11
Wabash silty clay	2
Wakeen silt loam	6
Waldeck fine sandy loam	9
Wann loam	9
Waurika silt loam	1
Woodson silt loam	1
Woodward loam	8
Wymore silty clay loam	1
Yahola sandy loam	9
Zaar silty clay	2
Zavala fine sandy loam	9
Zenda clay loam	5
Zook silty clay loam	1

1/ Loamy fine sand phases are placed in design group 11
2/ Loamy fine sand phases are placed in design group 3
3/ Loamy fine sand phases are placed in design group 9
4/ Irrigable in Finney County only
5/ Loamy fine sand phases are placed in design group 5

Irrigation Design Group 1

(Intake Family 0.1)

Deep soils with silt loam or silty clay loam surface layers and slowly to very slowly permeable heavy clay and claypan subsoils. Irrigation application generally does not penetrate below two feet unless shrinkage cracks during dry weather are somewhat extensive and deep.

Depth	Available Water Capacity
1'	2.3"
2'	4.0"
3'	5.9"

Butler silt loam
Cherokee silt loam
Grundy silty clay loam
Haig silty clay loam
Irwin silty clay loam
Kenoma silt loam
Kirkland silt loam
Ladysmith silty clay loam
Leanna silt loam
Lockhard silt loam
Lofton silty clay loam
Longford silt loam
Mayes silty clay loam
Parsons silt loam
Pawnee clay loam
Pleasant silty clay loam
Renfrow clay loam
Smolan silty clay loam
Spearville silty clay loam
Tabler clay loam
Waurika silt loam
Woodson silt loam
Wymore silty clay loam
Zook silty clay loam

Irrigation Design Group 2

(Intake Family 0.1)

Deep soils with silty clay or clay textures throughout. Occasional silty clay loam phases occur. Surface infiltration and subsoil permeability are very slow when the soil is moist. Shrinkage on drying causes extensive cracking which results in high rates of water acceptance until swelling occurs.

Depth	Available Water Capacity
1'	1.6"
2'	3.1"
3'	4.6"

Bowdoin clay loam
Goessel silty clay
Mangum clay
Ness silty clay
New Cambria silty clay
Onawa silty clay loam
Osage silty clay
Promise clay
Randall clay
Solomon silty clay
Sutphen silty clay
Wabash silty clay
Zaar silty clay

Irrigation Design Group 3

(Intake Family 0.3)

Deep soils with silt loam, loam, clay loam, or silty clay loam surface layers and clay loam, silty clay loam or silty clay subsoils. Subsoil permeability is slow to moderately slow. Shrinkage cracks that result from drying in the soils with more clayey subsoil textures allow water acceptance sufficient for this design.

Depth	Available Water Capacity
1'	2.3"
2'	4.3"
3'	6.3"
4'	8.4"
5'	10.6"

Bethany silt loam
Blanket silt loam
Bowdoin loamy fine sand
Bremer silty clay loam
Brewer silty clay loam
Carlson silt loam
Carwile fine sandy loam
Chase silty clay loam
Church silty clay loam
Crete silt loam
Dennis silt loam
Detroit silty clay loam
Drummond silt loam [1/]
Gymer silt loam
Harney silt loam
Hastings silt loam
Kimo silty clay loam
Lanton silty clay loam
Lubbock silty clay loam
Martin silty clay loam
Mento silt loam
Missler silty clay loam
Okemah silt loam
Richfield silt loam
Ryus silty clay loam
Sharpsburg silty clay loam
Summit silty clay loam
Tully silty clay loam

[1/] Irrigable in Finney County only

Irrigation Design Group 4

(Intake Family 0.3)

Moderately deep soils with silt loam, clay loam or silty clay loam surface layers and clay loam or silty clay subsoils with predominantly moderately slow permeability.

Depth	Available Water Capacity
1'	2.2"
2'	4.3"
2.5'	5.4"

Corinth silty clay loam
Girard silty clay loam
Labette silty clay loam
Las clay loam
Lesho clay loam
Oska silty clay loam

Irrigation Design Group 5

(Intake Family 0.5)

Deep soils with silt loam, loam, clay loam or silty clay loam surface layers and subsoils. Subsoil permeability is moderate to moderately slow.

Depth	Available Water Capacity
1'	2.5"
2'	4.9"
3'	7.1"
4'	9.4"
5'	11.7"

Angelus silt loam
Armo loam
Bippus clay loam
Bridgeport silt loam
Burchard clay loam
Caruso loam
Case clay loam
Clairemont silt loam
Clark clay loam
Colby silt loam
Coly silt loam
Corbin silt loam
Cozad silt loam
Dale clay loam
Elkader silt loam
Elmont silt loam
Eltree silt loam
Farnum loam
Geary silt loam
Goshen silt loam
Grant silt loam
Grigston silt loam
Hall silt loam
Hepler silt loam
Hobbs silt loam
Holdrege silt loam
Hord silt loam
Humbarger loam
Ivan silt loam
Judson silt loam
Kahola silt loam
Kaski loam
Keith silt loam
Kennebec silt loam
Kim clay loam
Leshara clay loam
Lula silt loam
Mansic clay loam
Manvel silt loam
Mason silt loam
McCune silt loam
Milan loam
Minnequa silt loam
Monona silt loam
Morrill loam
Muir silt loam
Norge silt loam
Nuckolls silt loam
Ost clay loam
Penden clay loam
Pond Creek silt loam
Port silt loam
Radley silt loam
Reading silt loam
Richfield loamy fine sand
Roxbury silt loam
Ruella loam
Satanta loam
Shelby loam
Tobin silt loam
Uly silt loam
Ulysses silt loam
Vanoss silt loam
Verdigris silt loam
Zenda clay loam

Irrigation Design Group 6

(Intake Family 0.5)

Moderately deep soils with silt loam or loam surface layers and loam, clay loam or silty clay loam subsoils with moderate to moderately slow permeability.

Depth	Available Water Capacity
1'	2.3"
2'	4.3"
3'	6.4"

Campus loam
Catoosa silt loam
Kingfisher silt loam
Mansker clay loam
Wakeen silt loam

Irrigation Design Group 7

(Intake Family 1.0)

Deep soils with silt loam, loam or very fine sandy loam surface layers and moderately permeable, medium textured subsoils.

Depth	Available Water Capacity
1'	2.0"
2'	4.0"
3'	5.9"
4'	7.8"
5'	9.4"

Cleora fine sandy loam
Dalhart fine sandy loam
Eudora silt loam
Haynie silt loam
Kenesaw silt loam
Konawa fine sandy loam
Manter fine sandy loam
McCook silt loam
Minco silt loam
Naron fine sandy loam
Reinach silt loam
Shellabarger fine sandy loam

Irrigation Design Group 8

(Intake Family 1.0)

Moderately deep soils with silt loam, loam or very fine sandy loam surface layers and moderately permeable clay loam, loam, or silt loam subsoils.

Depth	Available Water Capacity
1'	2.1"
2'	4.1"
2.5'	5.3"

Bates loam
Lancaster loam
Nash loam
Nashville silt loam
Sibleyville loam
Stephenville fine sandy loam
Woodward loam

Irrigation Design Group 9

(Intake Family 1.5)

Deep soils with fine sandy loam and loam surface layers and subsoils that have moderately rapid permeability. Available water capacity is moderate to low.

Depth	Available Water Capacity
1'	1.9"
2'	3.8"
3'	5.6"
4'	7.2"
5'	8.4"

Anselmo fine sandy loam
Attica fine sandy loam
Bayard fine sandy loam
Canadian fine sandy loam
Carr fine sandy loam
Cass fine sandy loam
Crisfield fine sandy loam
Dalhart loamy fine sand
Gerlane fine sandy loam
Glenberg fine sandy loam
Munjor sandy loam
Ortello fine sandy loam
Otero fine sandy loam
Plevna fine sandy loam
Shellabarger loamy fine sand
Waldeck fine sandy loam
Wann loam
Yahola sandy loam
Zavala fine sandy loam

Irrigation Design Group 10

(Intake Family 1.5)

Soils are moderately deep over sand with sandy loam to loam surface layers and moderately rapid to rapidly permeable subsoils with low available water capacity.

Depth	Available Water Capacity
1'	1.3"
2'	2.6"
3'	3.3"
4'	3.8"
5'	4.3"

Albion sandy loam
Las Animas sandy loam

Irrigation Design Group 11

(Intake Family 2.0)

Deep soils with loamy fine sand or loamy sand surface layers and moderately rapid to rapidly permeable subsoils.

Depth	Available Water Capacity
1'	0.9"
2'	2.1"
3'	3.2"
4'	4.4"
5'	5.7"

Attica loamy fine sand
Pratt loamy fine sand
Vona loamy fine sand

Irrigation Design Group 12

(Intake Family 3.0)

Deep rapidly permeable soils with sand or fine sand textures throughout.

Depth	Available Water Capacity
1'	0.8"
2'	1.6"
3'	2.4"
4'	3.1"
5'	3.8"

Boel fine sandy loam
Dillwyn loamy fine sand
Dwyer loamy fine sand
Elsmere loamy fine sand
Inavale loamy sand
Likes loamy sand
Lincoln sand
Platte loam
Sarpy loamy fine sand
Thurman loamy fine sand
Tivoli fine sand

Irrigation Design Group Number

For

Soils of a County or Survey Area

____

County or Survey Area

Use this sheet to list the irrigable soils within a county or an area. Enter published or field mapping symbol, soil name, and applicable irrigation design group number. Add pages as needed.

Mapping Unit or Published Symbol	Soil Name	Irrigation Design Group Number

PART 4 - GRAVITY IRRIGATION
DESIGN CRITERIA AND DESIGN GUIDE SHEETS

The irrigation design group is shown on the upper right-hand portion of each sheet.

Irrigation design groups are composed of soils that most nearly fit into a given soil intake family as shown in the following chart.

Soils in Design Group No.	Soil Intake Family of Nearest Fit						
	0.1	0.3	0.5	1.0	1.5	2.0	3.0
1 and 2	x						
3 and 4		x					
5 and 6			x				
7 and 8				x			
9 and 10					x		
11						x	
12							x

A. Column 1 - Crops

This column shows the major crops which are irrigated. No attempt has been made to justify the irrigation of crops from an economic cost-return standpoint. The guide considers soils, crops, and irrigation methods only. Table 4.2 lists the crops considered.

B. Column 2 - Normal Irrigation Depth

This is the normal irrigation depth to maintain an adequate moisture supply for the maturing crop grown under proper irrigation on the specific soil. Preplanting irrigations will normally fill the plant root zone and normal irrigations will replenish the moisture subsequently used. The guide is for the normal irrigation application only.

C. Column 3 - Net Moisture to be Replaced Each Irrigation

This column shows the net amount of water to be replaced for each crop during a normal irrigation. This value was obtained by determining the available water capacity in the root zone for the irrigated depth specified in Column 2 then selecting

either double the amount of AWC in the top one-fourth of the root zone or one-half the amount of AWC in the full root zone whichever is greater. This value has been rounded to the nearest 0.5 inch, except in the case of 60" furrow irrigation spacing in which case the alternate row being irrigated will receive 0.5" additional net moisture but the alternate dry row will be partially irrigated so the overall net application is usually an odd value, somewhat less than the uniform specified net irrigation for 40" rows.

D. Column 4 - Adapted Conservation Irrigation Methods

1. Level Borders - Level borders are those having a total fall of not more than one-half the design depth of application.

2. Graded Borders - Graded borders are those having a grade in excess of that listed for level borders. In this guide graded borders are listed for alfalfa, small grain, and grass up to 1.0% on 0.1 and 0.3 intake family soils; for alfalfa, small grain and grass up to 2.0% on 0.5 intake family soils; for alfalfa and small grain up to 2% and grass up to 4% on 1.0 and 1.5 intake family soils.

   Criteria for graded borders: The design of graded borders is based on the theory that if the gross application is applied in the needed net opportunity time, a balance of advance and recession streams will result.

   Due to the difficulty in obtaining uniform spread of water between border dikes, graded borders, unless supported by corrugations, are not recommended when the unit stream is less than

$$q = \frac{0.006\ (S^{0.5})}{n}$$

   S = Slope in ft./ft.

   n = Manning's coefficient

   (See Table 6.5, page 6-7.)

3. Corrugations - Corrugations are shown for the irrigation of close growing crops, such as alfalfa, and small grain on design slopes of 0.7% to 1.5% and for pasture grasses on design slopes of 0.7% to 3.0%. In addition, corrugations are to be used where specified on flatter slopes

where mechanical means is needed to obtain uniform spreading of water on border systems. Corrugation maximum stream size is 8 g.p.m.

4. <u>Furrows</u> - Furrows are shown for the irrigation of row crops including corn, sorghum, sugar beets, field beans and soybeans. Criteria is given for slopes up to 1.0 percent on all soils that are suitable for furrow irrigation.

    C - <u>Cutback Irrigation</u> - Water is applied at a faster (initial) rate at the beginning of the irrigation period and then reduced or cutback to a lesser rate, usually one-half the initial rate.

    R - <u>Re-use Irrigation</u> - This method of irrigation utilizes a tailwater recovery system for storing and re-using the excess water. Water is applied to the rows at the initial rate for the entire irrigation interval. Excess water may be re-applied to the same or to another field.

5. <u>Contour Furrows</u> - These may be used for row crop, particularly with terraces using a furrow with relatively large water carrying capacity, on field slopes of 0.60 percent to 6.0 percent. The furrows are run across the slope on a designed grade, usually 0.4 percent.

6. <u>Sprinklers</u> - The adaptability of sprinkler irrigation for the crops, soils and slopes listed and the net irrigation application are given. Because of the numerous sprinkler irrigation types and their varied application techniques, specific design criteria are not given. The narrative section on sprinkler irrigation and appropriate tables will aid the user of the guide in giving technical assistance for the various methods of sprinkler irrigation (see Part 5).

E. <u>Column 5 - Maximum Size Stream for Furrows and Corrugations</u>

Information in this column applies to furrows and corrugations only. The maximum stream is calculated based on three limitations: (1) soil intake, (2) maximum non-erosive stream and (3) furrow or corrugation capacity. The stream shown is the most limiting of the above three maximum streams. The values used for each of these items are as follows:

(1)		(2)		(3)	
Irrigation Design Group	Maximum Stream (gpm)	Design Slope Group	Maximum Non-Erosive Stream (gpm)	Furrow or Corrugation Spacing(In.)	Maximum Stream (gpm)
1 & 2	30	0.1 & 0.2	50	20 20	8 Cor. 15 Fur.
3 & 4	40	0.4	30	22	20
5 to 12	50	0.7	17	30	30
		1.5	8	36	40
		3.0	4	40	50
				60	40

Where field experience dictates that a larger stream than the maximum shown can be safely used, the maximum furrow length can be increased proportionally.

F. <u>Column 6 - Unit Streams</u>

1. <u>Borders or Flooding</u> - A unit stream is the stream required for a strip one foot wide and 100 feet long. The stream given is in cubic feet per second. The unit stream needed to apply the gross application in the needed opportunity time was calculated by the formula:

$$q = \frac{Fn}{7.2\ T_o\ E}$$

where q = unit stream - c.f.s. per foot of width per 100 feet of length

Fn = net irrigation application in inches

T_o = needed opportunity time in minutes from intake curve

E = estimated efficiency expressed as a decimal

Table 6.3, page 6-5, gives proper size unit streams for border irrigation. The actual stream required to irrigate a given area will be the product of the unit stream times the length of the area irrigated in hundreds of feet times the width of the area in feet, or

$$Q = \frac{q\ l\ w}{100}$$

where Q = required irrigation stream - c.f.s.

q = required unit stream - c.f.s.

w = width of the border - feet

l = length of the border - feet

2. Furrows or Corrugations - The stream size is the stream needed in g.p.m. per 100 feet to apply the planned gross application efficiently. It is determined by multiplying the average furrow intake rate for the planned net application by a factor of 1.5 to give proper travel time to the advancing furrow stream.

The furrow intake was determined using the following formula:

$$F_a = (gat^b)\left(W_1 + \frac{4}{3}\frac{dt}{y}^{0.5}\right) \leq gat^b \quad \text{(See Tables 6.8 \& 6.9)}$$

$$I_a = \frac{60\ F_a}{t} \quad \text{(See Tables 6.8 \& 6.9)}$$

where F_a = average intake in inches

g = variable factor depending on intake family, tillage, and crop residue

a & b = intake values from intake family formula

t = opportunity time in minutes

W_1 = top width of furrow stream

d = variable depending on intake family

y = inches per inch - water holding capacity of soil at time of irrigation

W_2 = furrow spacing in inches

I_a = average furrow intake in inches per hour

Example for use of furrow tables:

Example: intake family 0.5

Net application 3.0"

$g = .65 \quad s = .002$

Field length = 1300'

Solve for: 30, 40, and 60" spacing

Form Table 6.8 $T_o = 7.0$ $I_a = .43$ LS = 22

Determine "q" from formula $q = .13W_2I_a$ (or use Table 6.9)

where W_2 = furrow spacing in inches

then $q = 1.68$ for 30" spacing

$q = 2.24$ for 40" spacing

$q = 3.35$ for 60" spacing

$Q = 13 \times 1.68 = 22$ g.p.m. for 30" spacing

$Q = 13 \times 2.24 = 29$ g.p.m. for 40" spacing

$Q = 13 \times 3.35 = 44$ g.p.m. for 60" spacing

from Table 6.10 (parabolic furrows) for .002 grade

W_1 = 14" for 22 g.p.m.

W_1 = 16" for 29 g.p.m.

W_1 = 17" for 44 g.p.m.

For 30" spacing: Furrow wetted width = LS + W_1 = 22 + 14 = 36" (exceeds needed 30")

Therefore design for 30" is T_o = 7.0 hours and furrow stream = 22 g.p.m.

For 40" spacing: 22 + 16 = 38" (Furrow is slightly wider than the wetted irrigation width.)

Therefore design time = $\frac{40}{38} \times 7.0 = 7.4$ hours

Furrow stream = $\frac{38}{40} \times 29 = 28$ g.p.m.

For 60" spacing: 22 + 17 = 39"

Design time would be $\frac{60}{39} \times 7.0 = 10.8$ hours, which exceeds 35% of T_o

Therefore, increase T_o by 35% = $7.0 \times 1.35 = 9.5$ hours (Reference Item G.2., second paragraph, page 4-7.)

From Table 6.8 vertical intake for 9.5 hours by interpolation = 3.8" and LS = 25". 25 + 16 = 41" (adjusted wetted width).

(Note that W_1 used here is 16 not 17 because "Q" will be approximately 35% less than 44 g.p.m.)

Average intake is $\frac{41}{60}$ x 3.8 = 2.6". 2.6" in 9.5 hrs. = .27"/hr.

q = (.13)(60)(.27) = 2.1 g.p.m./100'

Q = 2.1 x 13 = 27 g.p.m.

G. <u>Column 7 - Maximum Border Width and Normal Furrow Spacing</u>

1. <u>Borders</u> - Border strip widths are dependent upon the size of irrigation stream available, the amount of cross slope to be overcome, the kind of equipment to be used in farming, and the accuracy of the land leveling in relation to the depths of flow anticipated. A width of about 15 feet is the practical minimum for hay and grain. Narrower strips are satisfactory for grass. Recommended border strips are as follows:

Irrigation Slope Group	Maximum Strip Width (Ft.)
Level	100
0.1,0.2 & 0.4	60
0.7	50
1.5	40
3.0	30

2. <u>Furrows and Corrugations</u> - Furrow spacing (inches) - The furrow spacing shown is what is customarily used. To account for alternate row irrigation or the "bed" with furrows method of row shaping, the 60" furrow spacing is included. Irrigation in 60" furrow spacings usually does not give lateral spread to the whole 60" furrow space. The amount of spread is computed to be the water surface width in the row (from Table 6.10) plus lateral spread (LS column in Table 6.8). This total subtracted from the row spacing is the dry width or unirrigated part of the furrow. Dry width ÷ row spacing = % dry.

   If "% dry" is less than 35 percent of the row spacing then opportunity time (T_o) is increased by the "% dry" amount and unit stream (q) is decreased by the "% dry" amount. If "% dry" is over 35 percent then opportunity time (T_o) is increased by 35 percent and unit stream is computed accordingly (see sample calculation, page 4-6).

   For corrugations, computations were made for 20" spacing.

H. Column 8 - Maximum Length of Run

1. Level Borders - The maximum length of run is based on a maximum flow depth of 0.5 foot and the distance water will travel during the 0.5 needed intake time. (See Table 6.1, page 6-3.)

2. Graded Borders - The maximum length of run is computed as the length that would be within the erosion limitations of the stream or the maximum practical size of border stream introduced at the upper end. Where this procedure gave a length in excess of 2600 feet, the border length was limited to 2600.

   The formulas for determining the maximum allowable non-erosive stream are as follows:

   For alfalfa and small grain -

   $$Q/W = 0.06\ (100\ S_o)^{-0.75}$$

   For grass -

   $$Q/W = 0.12\ (100\ S_o)^{-0.75}$$

   where Q = total discharge into the border in c.f.s.

   W = width of border in feet

   S_o = design slope or grade of border in ft./ft.

   The maximum stream was further restricted by assuming the maximum practical stream to be 0.075 c.f.s. per foot width of border. (See Tables 6.3, 6.4, 6.5, 6.6 and 6.7, pages 6-5 through 6-8.) If larger streams than shown are planned, design guidance should be obtained through the state office.

3. Furrows and Corrugations - Length of run is computed from the relationship of water intake characteristics of the soil, stream size and net irrigation application. This column value is found by dividing Column 5 by Column 6 and multiplying by 100. When this procedure produced a length in excess of 2600 feet, the maximum furrow stream in Column 5 was reduced to provide a furrow stream needed for 2600 feet length.

4. When more than one irrigation method will be used on the same field to accommodate a crop rotation, such as furrows one year and borders the next, then the length of run planned will be that which is the more restrictive.

I. <u>Column 9 - Estimated Field Efficiencies</u>

The field efficiencies shown are those considered realistic for the method of irrigation when good management practices are followed. Efficiency may be defined as the ratio of the quantity of water effectively put into the crop root zone and utilized by growing crops to the quantity delivered to the field. It is expressed as a percentage. It takes into consideration items such as evaporation, losses due to deep percolation, unequal distribution, and direct runoff. These efficiencies have been rounded to the nearest "5," i.e., 60, 65, 70, etc.

1. <u>Level Borders</u> - Estimated to be 80 percent regardless of crop.

2. <u>Graded Borders</u> - Estimated efficiency varies from 50 to 80 percent as shown in Table 6.3, page 6-5. It is based on relationship of time of application (T_A), the unit stream (q), and the desired net application (F_n).

3. <u>Furrows - Re-use Method</u> - When runoff water is recovered and pumped back into the system, an overall efficiency of approximately 80 to 85 percent is obtained. The lesser efficiency is associated with 0.1 intake family soils, with shallow application and with the steeper irrigation grades.

4. <u>Furrows - Cutback Method</u> - An efficiency of approximately 65 to 70 has been used for this method of application. The lesser efficiency is associated with shallow application or the steeper irrigation grades.

5. <u>Corrugations</u> - Efficiency shown is that expected, if proper size stream is applied according to soil intake rate. Sixty percent is shown, except for 0.1 intake family where 55 percent was used.

J. <u>Column 10 - Gross Water Used</u>

The total amount of water to be used per irrigation is found by dividing Column 3 by Column 9, i.e., net application divided by estimated field efficiency.

K. Column 11 - Estimated Time Required

1. Level Border - Time required to apply water is obtained from Table 6.7, page 6-8. Find time in minutes required to apply one inch of water using the designed unit stream "q" from Column 6. Multiply the gross irrigation application in Column 10 by this number of minutes and divide by 60 to convert to hours as shown in this column.

2. Graded Border - This is the time required to deliver the gross amount of water to be applied to the field. It is obtained by the formula:

$$T_A = \frac{F_G}{432q} \qquad \text{where } F_G = \frac{F_n}{E}$$

where T_A = application time in hours

F_G = gross depth to be applied - inches

q = unit stream

F_n = net application - inches

E = application efficiency as a decimal

Time of application (T_A) can be read directly in minutes from Table 6.3 for the specified conditions shown. Divide this amount by 60 for the value in this Column 11. Table 6.7 can also be used to calculate time required in the same manner as for level borders.

3. Furrows - This figure is the needed opportunity time (T_o) or time required for the net application to enter the soil. To determine opportunity time, first change unit furrow stream shown in Column 6 to average intake rate by dividing by 1.5. Then change this to inches per hour for appropriate furrow spacing by use of Table 6.11, page 6-12. Next, divide the net irrigation in Column 3 by this value to obtain the needed intake opportunity time (T_o).

4. Corrugations - Estimated time required is computed by changing g.p.m. per 100 feet in Column 6 to inches per hour as described for furrows. Then, divide the gross application by this value.

L. Limitations and Adaptations

Tables 4.1 and 4.2 are used to show various relationships and limitations of irrigation methods related to design

slope, intake family and crops. Table 4.3 is used to show crop limitations as related to design slope and irrigation design group. These relationships and limitations are accounted for in the irrigation design sheets for the 12 irrigation groups.

Judgment must be exercised in the use of this guide and should be used to fit local conditions. For example, the design guide sheets show forward grades of 0.1and 0.2% on 0.1 intake family soils also level and 0.1% grade on 0.3 intake family soils. This is reasonable in the western part of the state but in the eastern part forward grade preferably should be 0.3% or greater on clayey soils to avoid field wetness and poor farmability.

Table 4.1

Irrigation Method Adaptations

Method	Slope Group .00 to .04 / Design Slope Lev	Slope Group .05 to .14 / Design Slope 0.1	Slope Group .15 to .25 / Design Slope 0.2	Slope Group .26 to .55 / Design Slope 0.4	Slope Group .56 to 1.0 / Design Slope 0.7	Slope Group 1.1 to 2.0 / Design Slope 1.5	Slope Group 2.1 to 4.0 / Design Slope 3.0	Slope Group 4.1 to 8.0 / Design Slope 6.0	Intake Family 0.1	Intake Family 0.3	Intake Family 0.5	Intake Family 1.0	Intake Family 1.5	Intake Family 2.0	Intake Family 3.0	Limitations
Level Border	x									x	x	x	x			
Border		x	x	x	x	x	x		x	x	x	x	x			Limited use on 0.1 family Limited min. stream size 2-4% sod only
Corrugation					x	x	x		x	x	x	x				Max. stream size 8 g.p.m. 2-4% sod only
Furrow		x	x	x	x				x	x	x	x	x	x		Max. furrow grade 0.7 except LRA 72 & 77 - 1.0* Max. stream size 12/S
Contour Furrow w/Terraces					x	x	x	x		x	x	x	x			Design slope 0.4 40" row Design stream 20 g.p.m. Max. field slope 6.0%
Sprinkler		x	x	x	x	x	x	x	x	x	x	x	x	x	x	Intake equals or exceeds 0.1"/hr.
Non-erosive stream (Max.)			50	30	17	8	4									

*The location of Land Resource Areas (LRA's) 72 and 77, in this case, is defined as the counties of Decatur, Sheridan, Gove, Ness, Hodgeman, Ford, Meade and all counties west thereof. For furrow grades of 0.8 to 1.0% in LRA's 72 and 77 the maximum furrow stream is 13 g.p.m.

Table 4.2

Crop Adaptations to Methods

Crop	Row Space Inches	Normal Irrig. Depth Feet	Max. Stream Size gpm	Adapted Irrigation Methods						Limitations
				Level Border	Border	Corruga-tion	Furrow	Contour Furrow	Sprinkler	
Alfalfa	-	5	-	x	x	x			x	All Irrig. Groups except 12
Grass	-	3	-	x	x	x			x	
Corn and Sorghum	30 40 60	3	30 50 40	x			x	x	x	If drilled use border method (see small grain border)
Sugar Beets	22	3	20				x		x	All Irrig. Groups except 1, 11 & 12
Small Grain	30 40	3	30 50	x	x	x	x		x	
Beans	30 40 60	3	30 50 40	x			x	x	x	All Irrig. Groups except 11 & 12

Normal net irrigation application is 50% of available moisture capacity at normal irrigation depth.

Table 4.3

<u>Crop Adaptations Within Irrigation Design Groups</u>

<table>
<tr><th rowspan="4">Design Slope Group</th><th colspan="12">Irrigation Design Group No.</th></tr>
<tr><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th><th>7</th><th>8</th><th>9</th><th>10</th><th>11</th><th>12</th></tr>
<tr><th colspan="12">Intake Family</th></tr>
<tr><th>0.1</th><th>0.1</th><th>0.3</th><th>0.3</th><th>0.5</th><th>0.5</th><th>1.0</th><th>1.0</th><th>1.5</th><th>1.5</th><th>2.0</th><th>3.0</th></tr>
<tr><td>Level</td><td>None</td><td>None</td><td>Alf. & Grass</td><td>Alf. & Grass</td><td>All * except S. Beets</td><td>All * except S. Beets</td><td>All * except S. Beets</td><td>All * except S. Beets</td><td>All * except S. Beets</td><td>All * except S. Beets</td><td rowspan="8">All except Sugar Beets and Beans</td><td rowspan="8">Grass, Corn, Sorghum and Small Grain</td></tr>
<tr><td>0.1%</td><td rowspan="4">All except Sugar Beets</td><td rowspan="4">All except Sugar Beets</td><td>All</td><td>All</td><td>All</td><td>All</td><td>All</td><td>All</td><td>All</td><td>All</td></tr>
<tr><td>0.2%</td><td>All</td><td>All</td><td>All</td><td>All</td><td>All</td><td>All</td><td>All</td><td>All</td></tr>
<tr><td>0.4%</td><td>All</td><td>All</td><td>All</td><td>All</td><td>All</td><td>All</td><td>All</td><td>All</td></tr>
<tr><td>0.7%</td><td>All</td><td>All</td><td>All</td><td>All</td><td>All</td><td>All</td><td>All</td><td>All</td></tr>
<tr><td>1.5%</td><td>Alf. SG & Grass</td><td>Alf. SG & Grass</td><td>All</td><td>All</td><td>All</td><td>All</td><td>All</td><td>All</td><td>All</td><td>All</td></tr>
<tr><td>3.0%</td><td>None</td><td>None</td><td>All</td><td>All</td><td>All</td><td>All</td><td>All</td><td>All</td><td>All</td><td>All</td></tr>
<tr><td>6.0%</td><td>None</td><td>None</td><td>None</td><td>None</td><td>All except S. Beets</td><td>All except S. Beets</td><td>All except S. Beets</td><td>All except S. Beets</td><td>All except S. Beets</td><td>All except S. Beets</td></tr>
</table>

*Suitable for sugar beets under sprinkler

IRRIGATION DESIGN

U.S. DEPT. OF AGRICULTURE
SOIL CONSERVATION SERVICE

GENERAL SOILS DESCRIPTION: Deep soils with silt loam or silty clay loam surface layers and very slowly permeable subsoils. (Intake Family 0.1)

GROUP NO. 1

Sheet 1 of 1
Date 1975

CROPS	NORMAL IRRIGATION DEPTH feet	NET MOISTURE TO BE REPLACED EACH IRRIGATION inches	ADAPTED CONSERVATION IRRIGATION METHODS	MAXIMUM SIZE STREAM FOR FURROWS OR CORRUGATIONS g.p.m.	UNIT STREAM BORDERS OR CONTOUR DITCH C.F.S. PER 100 SQ.FT. FURROWS OR CORRUGATIONS G.P.M./100' OF LENGTH c.f.s. or g.p.m.	MAXIMUM BORDER WIDTH feet NORMAL FURROW OR CORRUGATION SPACING inches ft. or in.	MAXIMUM LENGTH OF RUN feet	EST. FIELD EFF. %	GROSS WATER USED inches	ESTIMATED TIME REQUIRED hours
1	2	3	4	5	6	7	8	9	10	11
SLOPE GROUP LESS THAN 0.05% (DESIGN SLOPE LEVEL)										
Irrigation not recommended.										
* * * * * * *	* * * *	* * * *	* * * * * *	* * * * *	* * * * *	* * * *	* * *	* *	* * * *	* * * * *
SLOPE GROUP 0.05 TO 0.25% (DESIGN SLOPES 0.1% AND 0.2%)										
Alfalfa, Grass or Small Grain	3.0	3.0	Border	-	0.00064*	60	2600	60	5.0	18.0
	2.0	2.0	Border	-	0.00064*	60	2600	60	3.3	12.0
Corn, Sorghum or Beans	2.5	2.5	Furrow	12	0.45	30	2600	60	4.2	24.0
		2.5	Furrow	16	0.60	40	2600	60	4.2	24.0
		2.5	Furrow	16	0.60	60	2600	60	4.2	36.0
	2.0	2.0	Furrow	13	0.48	30	2600	60	3.3	18.0
		2.0	Furrow	17	0.63	40	2600	60	3.3	18.0
		2.0	Furrow	19	0.72	60	2600	60	3.3	24.0
* * * * * * *	* * * *	* * * *	* * * * * *	* * * * *	* * * * *	* * * *	* * *	* *	* * * *	* * * * *
SLOPE GROUP 0.26 TO 0.55% (DESIGN SLOPE 0.4%)										
Alfalfa, Grass or Small Grain	3.0	3.0	Border	-	0.0007*	60	2600	55	5.5	18.0
	2.0	2.0	Border	-	0.0007*	60	2600	55	3.6	12.0
Corn, Sorghum or Beans	2.5	2.5	Furrow	12	0.45	30	2600	60	4.2	24.0
		2.5	Furrow	16	0.60	40	2600	60	4.2	24.0
		2.5	Furrow	16	0.60	60	2600	60	4.2	36.0
	2.0	2.0	Furrow	13	0.48	30	2600	60	3.3	18.0
		2.0	Furrow	17	0.63	40	2600	60	3.3	18.0
		2.0	Furrow	19	0.72	60	2600	60	3.3	24.0
* * * * * * *	* * * *	* * * *	* * * * * *	* * * * *	* * * * *	* * * *	* * *	* *	* * * *	* * * * *
SLOPE GROUP 0.56 TO 1.0% (DESIGN SLOPE 0.7%)										
Alfalfa, Grass or Small Grain	3.0	3.0	Border	-	0.00077*	50	2600	50	6.0	18.0
	2.5	2.5	Corrugation	8	0.33	20	2400	55	4.5	24.0
	2.0	2.0	Border	-	0.00077*	50	2600	55	3.6	12.0
		2.0	Corrugation		0.35	20	2300	55	3.6	18.0
Corn, Sorghum or Beans	2.5	2.5	Furrow	12	0.45	30	2600	60	4.2	24.0
		2.5	Furrow	16	0.60	40	2600	60	4.2	24.0
		2.5	Furrow	16	0.60	60	2600	60	4.2	36.0
	2.0	2.0	Furrow	13	0.48	30	2600	60	3.3	18.0
		2.0	Furrow	17	0.65	40	2600	60	3.3	18.0
		2.0	Furrow	17	0.65	60	2600	60	3.3	24.0
* * * * * * *	* * * *	* * * *	* * * * * *	* * * * *	* * * * *	* * * *	* * *	* *	* * * *	* * * * *
SLOPE GROUP 1.1 TO 2.0% (DESIGN SLOPE 1.5%)										
Alfalfa, Grass or Small Grain	2.0	2.0	Corrugation	8	0.35	20	2300	55	3.6	18.0
* * * * * * *	* * * *	* * * *	* * * * * *	* * * * *	* * * * *	* * * *	* * *	* *	* * * *	* * * * *
SLOPE GROUP OVER 2.0%										
Irrigation not recommended.										

*Corrugations are required to provide adequate spread of border stream.

IRRIGATION DESIGN

GENERAL SOILS DESCRIPTION: Deep soils with silty clay or clay textures throughout.

GROUP NO. 2

(Intake Family 0.1)

Sheet 1 of 1
Date 1975

OF AGRICULTURE
VATION SERVICE

S	NORMAL IRRIGATION DEPTH feet	NET MOISTURE TO BE REPLACED EACH IRRIGATION inches	ADAPTED CONSERVATION IRRIGATION METHODS	MAXIMUM SIZE STREAM FOR FURROWS OR CORRUGATIONS g.p.m.	UNIT STREAM BORDERS OR CONTOUR DITCH C.F.S. PER 100 SQ.FT. FURROWS OR CORRUGATIONS G.P.M./100' OF LENGTH c.f.s. or g.p.m.	MAXIMUM BORDER WIDTH feet NORMAL FURROW OR CORRUGATION SPACING inches ft. or in.	MAXIMUM LENGTH OF RUN feet	EST. FIELD EFF. %	GROSS WATER USED inches	ESTIMATED TIME REQUIRED hours
	2	3	4	5	6	7	8	9	10	11
		SLOPE GROUP LESS THAN 0.05% (DESIGN SLOPE LEVEL)								
			Irrigation not recommended.							
* * *	* * * * *	* * * *	* * * * * * *	* * * *	* * * * *	* * * *	* * * *	* *	* * * *	* * * * *
		SLOPE GROUP 0.05 TO 0.25% (DESIGN SLOPES 0.1 AND 0.2%)								
,Grass	3.0	2.5	Border	-	0.00096*	60	2600	60	4.2	10.0
l Grain										
	2.5	2.0	Border	-	0.00096*	60	2600	60	3.3	8.0
orghum	3.0	2.5	Furrow	16	0.60	30	2600	60	4.2	18.0
s		2.5	Furrow	21	0.80	40	2600	60	4.2	18.0
		2.5	Furrow	24	0.92	60	2600	60	4.2	24.0
	2.5	2.0	Furrow	19	0.71	30	2600	60	3.3	12.0
		2.0	Furrow	24	0.92	40	2600	60	3.3	12.0
		2.0	Furrow	26	0.98	60	2600	60	3.3	18.0
* * *	* * * * *	* * * *	* * * * * * *	* * * *	* * * * *	* * * *	* * * *	* *	* * * *	* * * * *
		SLOPE GROUP 0.26 TO 0.55% (DESIGN SLOPE 0.4%)								
,Grass	3.0	2.5	Border	-	0.0011*	60	2600	55	4.6	10.0
l Grain		2.5	Corrugation	8	0.45	20	1800	55	4.6	18.0
	2.5	2.0	Border	-	0.0011*	60	2600	55	3.6	8.0
		2.0	Corrugation	8	0.52	20	1500	55	3.6	12.0
orghum	3.0	2.5	Furrow	16	0.60	30	2600	60	4.2	18.0
s		2.5	Furrow	21	0.80	40	2600	60	4.2	18.0
		2.5	Furrow	24	0.92	60	2600	60	4.2	24.0
	2.5	2.0	Furrow	19	0.71	30	2600	60	3.3	12.0
		2.0	Furrow	24	0.92	40	2600	60	3.3	12.0
		2.0	Furrow	26	0.98	60	2600	60	3.3	18.0
* * *	* * * * *	* * * *	* * * * * * *	* * * *	* * * * *	* * * *	* * * *	* *	* * * *	* * * * *
		SLOPE GROUP 0.56 TO 1.0% (DESIGN SLOPE 0.7%)								
,Grass	3.0	2.5	Border	-	0.0010*	50	2600	50	5.0	10.0
l Grain		2.5	Corrugation	8	0.45	20	1800	55	4.6	18.0
	2.5	2.0	Border	-	0.0012*	50	2600	50	4.0	8.0
		2.0	Corrugation	8	0.52	20	1500	55	3.6	12.0
orghum	3.0	2.5	Furrow	16	0.60	30	2600	60	4.2	18.0
s		2.5	Furrow	17	0.65	40	2600	60	4.2	20.0
		2.5	Furrow	17	0.65	60	2600	60	4.2	30.0
	2.5	2.0	Furrow	17	0.65	30	2600	60	3.3	12.0
		2.0	Furrow	17	0.65	40	2600	60	3.3	16.0
		2.0	Furrow	17	0.65	60	2600	60	3.3	24.0
* * *	* * * * *	* * * *	* * * * * * *	* * * *	* * * * *	* * * *	* * * *	* *	* * * *	* * * * *
		SLOPE GROUP 1.1 TO 2.0% (DESIGN SLOPE 1.5%)								
,Grass	2.5	2.0	Corrugation	8	0.52	20	1500	55	3.6	12.0
l Grain										
* * *	* * * * *	* * * *	* * * * * * *	* * * *	* * * * *	* * * *	* * * *	* *	* * * *	* * * * *
			SLOPE GROUP OVER 2.0%							
			Irrigation not recommended.							
ations are required to provide adequate spread of border stream										

IRRIGATION DESIGN

U.S. DEPT. OF AGRICULTURE
SOIL CONSERVATION SERVICE

GENERAL SOILS DESCRIPTION: Deep soils with silt loam, clay loam or silty clay loam surface layers and subsoils with slow to moderately slow permeability. (Intake Family 0.3)

GROUP NO 3

Sheet 1 of 3 Date 1975

CROPS	NORMAL IRRIGATION DEPTH	NET MOISTURE TO BE REPLACED EACH IRRIGATION	ADAPTED CONSERVATION IRRIGATION METHODS	MAXIMUM SIZE STREAM FOR FURROWS OR CORRUGATIONS	UNIT STREAM BORDERS OR CONTOUR DITCH C.F.S. PER 100 SQ.FT. FURROWS OR CORRUGATIONS G.P.M./100' OF LENGTH	MAXIMUM BORDER WIDTH feet NORMAL FURROW OR CORRUGATION SPACING inches	MAXIMUM LENGTH OF RUN	EST. FIELD EFF.	GROSS WATER USED	ESTIMATED TIME REQUIRED
	feet	inches		g.p.m.	c.f.s. or g.p.m.	ft. or in.	feet	%	inches	hours
1	2	3	4	5	6	7	8	9	10	11
		SLOPE GROUP LESS THAN 0.05% (DESIGN SLOPE LEVEL)								
Alfalfa	4.0	5.0	Level Border	-	0.0021	100	2100	80	6.2	6.6
			Sprinkler							
Grass	3.0	3.5	Level Border	-	0.0035	100	1700	80	4.4	3.0
			Sprinkler							
* * *	* * *	* * *	* * *	* * *	* * *	* * *	* * *	* * *	* * *	* * *
		SLOPE GROUP 0.05 TO 0.14% (DESIGN SLOPE 0.1%)								
Alfalfa	4.0	5.0	Border	-	0.0013	60	2600	65	7.7	14.0
			Sprinkler							
Corn, Sorghum or Beans	3.0	3.5	Furrow-R	26	1.0	30	2600	85	4.1	16.3
		3.5	Furrow-C	26	1.0	30	2600	70	5.0	13.8
		3.5	Furrow-R	34	1.3	40	2600	85	4.1	16.3
		3.5	Furrow-C	34	1.3	40	2600	70	5.0	13.8
		3.3	Furrow-R	39	1.5	60	2600	85	3.9	20.0
		3.3	Furrow-C	39	1.5	60	2600	70	4.7	17.0
			Sprinkler							
Sugar Beets	3.0	3.5	Furrow-R	18	0.7	22	2600	85	4.1	16.3
		3.5	Furrow-C	18	0.7	22	2600	70	5.0	13.8
			Sprinkler							
Small Grain	3.0	3.5	Border	-	0.0016	60	2600	65	5.4	8.0
		3.5	Furrow-R	26	1.0	30	2600	85	4.1	16.3
		3.5	Furrow-C	26	1.0	30	2600	70	5.0	13.8
		3.5	Furrow-R	34	1.3	40	2600	85	4.1	16.3
		3.5	Furrow-C	34	1.3	40	2600	70	5.0	13.8
			Sprinkler							
Grass	3.0	3.5	Border	-	0.0016	60	2600	65	5.4	8.0
			Sprinkler							
* * *	* * *	* * *	* * *	* * *	* * *	* * *	* * *	* * *	* * *	* * *
		SLOPE GROUP 0.15 TO 0.25% (DESIGN SLOPE 0.2%)								
Alfalfa	4.0	5.0	Border	-	0.0015	60	2600	55	9.0	14.0
			Sprinkler							
Corn, Sorghum or Beans	3.0	3.5	Furrow-R	26	1.0	30	2600	85	4.1	16.3
		3.5	Furrow-C	26	1.0	30	2600	70	5.0	13.8
		3.5	Furrow-R	34	1.3	40	2600	85	4.1	16.3
		3.5	Furrow-C	34	1.3	40	2600	70	5.0	13.8
		3.3	Furrow-R	39	1.5	60	2600	85	3.9	20.3
		3.3	Furrow-C	39	1.5	60	2600	70	4.7	17.2
			Sprinkler							
Sugar Beets	3.0	3.5	Furrow-R	18	0.7	22	2600	85	4.1	16.3
			Furrow-C	18	0.7	22	2600	70	5.0	13.8
			Sprinkler							
Small Grain	3.0	3.5	Border	-	0.00175	60	2600	60	5.8	8.3
		3.5	Furrow-R	26	1.0	30	2600	85	4.1	16.3
		3.5	Furrow-C	26	1.0	30	2600	70	5.0	13.8
		3.5	Furrow-R	34	1.3	40	2600	85	4.1	16.3
		3.5	Furrow-C	34	1.3	40	2600	70	5.0	13.8
			Sprinkler							
Grass	3.0	3.5	Border	-	0.00175	60	2600	60	5.8	8.3
			Sprinkler							
	R =	Reuse	C = Cutback							

IRRIGATION DESIGN

U.S. DEPT. OF AGRICULTURE
SOIL CONSERVATION SERVICE

GENERAL SOILS DESCRIPTION: Deep soils with silt loam, clay loam or silty clay loam surface layers and subsoils with slow to moderately slow permeability. (Intake Family 0.3)

GROUP NO 3

Sheet 2 of 3

Date 1975

CROPS	NORMAL IRRIGATION DEPTH	NET MOISTURE TO BE REPLACED EACH IRRIGATION	ADAPTED CONSERVATION IRRIGATION METHODS	MAXIMUM SIZE STREAM FOR FURROWS OR CORRUGATIONS	UNIT STREAM BORDERS OR CONTOUR DITCH C.F.S. PER 100 SQ.FT. FURROWS OR CORRUGATIONS G.P.M./100' OF LENGTH	MAXIMUM BORDER WIDTH feet NORMAL FURROW OR CORRUGATION SPACING inches	MAXIMUM LENGTH OF RUN	EST. FIELD EFF.	GROSS WATER USED	ESTIMATED TIME REQUIRED
	feet	inches		g.p.m	c.f.s. or g.p.m.	ft. or in.	feet	%	inches	hours
1	2	3	4	5	6	7	8	9	10	11
		SLOPE GROUP 0.26 TO 0.55% (DESIGN SLOPE 0.4%)								
Alfalfa	3.5	4.0	Border	–	0.0019*	60	2600	50	8.0	10.0
			Sprinkler							
Corn, Sorghum or Beans	3.0	3.5	Furrow-R	26	1.0	30	2600	85	4.1	16.3
		3.5	Furrow-C	26	1.0	30	2600	70	5.0	13.8
		3.5	Furrow-R	30	1.3	40	2300	85	4.1	16.3
		3.5	Furrow-C	30	1.3	40	2300	70	5.0	13.8
		3.3	Furrow-R	30	1.4	60	2150	85	3.9	20.9
		3.3	Furrow-C	30	1.4	60	2150	70	4.7	17.7
			Sprinkler							
Sugar Beets	3.0	3.5	Furrow-R	18	0.7	22	2600	85	4.1	16.3
		3.5	Furrow-C	18	0.7	22	2600	70	5.0	13.8
			Sprinkler							
Small Grain	3.0	3.5	Border	–	0.0021*	60	2600	50	7.0	8.3
		3.5	Furrow-R	26	1.0	30	2600	85	4.1	16.3
		3.5	Furrow-C	26	1.0	30	2600	70	5.0	13.8
		3.5	Furrow-R	30	1.3	40	2300	85	4.1	16.3
		3.5	Furrow-C	30	1.3	40	2300	70	5.0	13.8
			Sprinkler							
Grass	3.0	3.5	Border	–	0.0021*	60	2600	50	7.0	8.3
			Sprinkler							
* * * * * * *	* * * *	* * * *	* * * * * *	* * * *	* * * * *	* * * *	* * * *	* *	* * * *	* * * * *
		SLOPE GROUP 0.56 TO 1.0% (DESIGN SLOPE 0.7%)								
Alfalfa or Grass	3.0	3.5	Border	–	0.0021*	50	2600	50	7.0	8.3
		3.5	Corrugation	8	0.65	20	1230	60	5.8	13.8
			Sprinkler							
Corn, Sorghum or Beans	3.0	3.5	Furrow-R	17	1.0	30	1700	80	4.4	16.3
		3.5	Furrow-C	17	1.0	30	1700	65	5.4	13.8
		3.5	Furrow-R	17	1.3	40	1300	80	4.4	16.3
		3.5	Furrow-C	17	1.3	40	1300	65	5.4	13.8
		3.1	Furrow-R	17	1.3	60	1310	80	3.9	21.9
		3.1	Furrow-C	17	1.3	60	1310	65	4.8	18.6
			Contour Furrow	(Refer to 30" or 40" furrow with design slope 0.4%)						
			Sprinkler							
Sugar Beets	3.0	3.5	Furrow-R	17	0.7	22	2400	80	4.4	16.3
			Furrow-C	17	0.7	22	2400	65	5.4	13.8
			Sprinkler							
Small Grain	3.0	3.5	Border	–	0.0021*	50	2600	50	7.0	8.3
		3.5	Furrow-R	17	1.0	30	1700	80	4.4	16.3
		3.5	Furrow-C	17	1.0	30	1700	65	5.4	13.8
		3.5	Furrow-R	17	1.3	40	1300	80	4.4	16.3
		3.5	Furrow-C	17	1.3	40	1300	65	5.4	13.8
		3.5	Corrugation	8	0.65	20	1230	60	5.8	13.8
			Sprinkler							

R = Reuse   C = Cutback

*Corrugations are required to provide adequate spread of border stream

IRRIGATION DESIGN

U.S. DEPT. OF AGRICULTURE
SOIL CONSERVATION SERVICE

GENERAL SOILS DESCRIPTION: Deep soils with silt loam, clay loam or silty clay loam surface layers and subsoils with slow to moderately slow permeability. (Intake Family 0.3)

GROUP NO. 3

Sheet 3 of 3
Date 1975

CROPS	NORMAL IRRIGATION DEPTH feet	NET MOISTURE TO BE REPLACED EACH IRRIGATION inches	ADAPTED CONSERVATION IRRIGATION METHODS	MAXIMUM SIZE STREAM FOR FURROWS OR CORRUGATIONS g.p.m.	UNIT STREAM BORDERS OR CONTOUR DITCH C.F.S. PER 100 SQ.FT. FURROWS OR CORRUGATIONS G.P.M./100' OF LENGTH c.f.s. or g.p.m.	MAXIMUM BORDER WIDTH feet NORMAL FURROW OR CORRUGATION SPACING inches ft. or in.	MAXIMUM LENGTH OF RUN feet	EST. FIELD EFF. %	GROSS WATER USED inches	ESTIMATED TIME REQUIRED hours
1	2	3	4	5	6	7	8	9	10	11
SLOPE GROUP 1.1 TO 2.0% (DESIGN SLOPE 1.5%)										
Alfalfa, Grass or Small Grain	3.0	3.5	Corrugation Sprinkler	8	0.65	20	1230	60	5.8	13.8
Corn, Sorghum or Beans	3.0	3.5	Contour Furrow (Refer to 30" or 40" furrow with design slope 0.4%) Sprinkler							
Sugar Beets	3.0	3.5	Sprinkler							
* * * * * * *	* * * *	* * * *	* * * * * *	* * * *	* * * *	* * * *	* * *	* *	* * * *	* * * *
SLOPE GROUP 2.1 TO 4.0% (DESIGN SLOPE 3%) (Contour furrow or sprinkler with terraces)										
Alfalfa, S. Beets or Small Grain	3.0	3.5	Sprinkler							
Corn, Sorghum or Beans	3.0	3.5	Contour Furrow (Refer to 30" or 40" furrow with design slope 0.4%) Sprinkler							
Grass	3.0	3.5	Corrugation Sprinkler	4	0.65	20	620	60	5.8	13.8
* * * * * * *	* * * *	* * * *	* * * * * *	* * * *	* * * *	* * * *	* * *	* *	* * * *	* * * *
SLOPE GROUP 4.1 TO 8.0% (DESIGN SLOPE 6.0%)										
Irrigation not recommended.										

IRRIGATION DESIGN

U.S. DEPT. OF AGRICULTURE
SOIL CONSERVATION SERVICE

GENERAL SOILS DESCRIPTION Moderately deep soils with silt loam, clay loam or silty clay loam surface layers and subsoils with predominantly moderately slow permeability. (Intake Family 0.3)

GROUP NO 4

Sheet 1 of 3

Date 1975

CROPS	NORMAL IRRIGATION DEPTH feet	NET MOISTURE TO BE REPLACED EACH IRRIGATION inches	ADAPTED CONSERVATION IRRIGATION METHODS	MAXIMUM SIZE STREAM FOR FURROWS OR CORRUGATIONS g.p.m.	UNIT STREAM BORDERS OR CONTOUR DITCH C.F.S. PER 100 SQ.FT. FURROWS OR CORRUGATIONS G.P.M./100' OF LENGTH c.f.s. or g.p.m.	MAXIMUM BORDER WIDTH feet NORMAL FURROW OR CORRUGATION SPACING inches ft. or in.	MAXIMUM LENGTH OF RUN feet	EST. FIELD EFF. %	GROSS WATER USED inches	ESTIMATED TIME REQUIRED hours
1	2	3	4	5	6	7	8	9	10	11
		SLOPE GROUP LESS THAN 0.05% (DESIGN SLOPE LEVEL)								
Alfalfa or Grass	2.5	3.0	Level Border	-	0.0041	100	1500	80	3.8	2.2
			Sprinkler							
* * * * * *	* * * *	* * * *	* * * * * *	* * * *	* * * *	* * * *	* * * *	* *	* * * *	* * * * *
		SLOPE GROUP 0.05 TO 0.14% (DESIGN SLOPE 0.1%)								
Alfalfa or Grass	2.5	3.0	Border	-	0.0017	60	2600	65	4.6	6.3
			Sprinkler							
Corn, Sorghum	2.5	3.0	Furrow-R	26	1.0	30	2600	85	3.5	13.1
or Beans		3.0	Furrow-C	26	1.0	30	2600	70	4.3	11.1
		3.0	Furrow-R	36	1.4	40	2600	85	3.5	13.1
		3.0	Furrow-C	36	1.4	40	2600	70	4.3	11.1
		2.8	Furrow-R	39	1.5	60	2600	85	3.3	16.6
		2.8	Furrow-C	39	1.5	60	2600	70	4.0	14.1
			Sprinkler							
Sugar Beets	2.5	3.0	Furrow-R	20	0.8	22	2500	85	3.5	13.1
			Furrow-C	20	0.8	22	2500	70	4.3	11.1
			Sprinkler							
Small Grain	2.5	3.0	Border	-	0.0017	60	2600	65	4.6	6.3
		3.0	Furrow-R	26	1.0	30	2600	85	3.5	13.1
		3.0	Furrow-C	26	1.0	30	2600	70	4.3	11.1
		3.0	Furrow-R	36	1.4	40	2600	85	3.5	13.1
		3.0	Furrow-C	36	1.4	40	2600	70	4.3	11.1
			Sprinkler							
* * * * * *	* * * *	* * * *	* * * * * *	* * * *	* * * *	* * * *	* * * *	* *	* * * *	* * * * *
		SLOPE GROUP 0.15 TO 0.25% (DESIGN SLOPE 0.2%)								
Alfalfa or Grass	2.5	3.0	Border	-	0.0018	60	2600	60	5.0	6.5
			Sprinkler							
Corn, Sorghum	2.5	3.0	Furrow-R	26	1.0	30	2600	85	3.5	13.1
or Beans		3.0	Furrow-C	26	1.0	30	2600	70	4.3	11.1
		3.0	Furrow-R	36	1.4	40	2600	85	3.5	13.1
		3.0	Furrow-C	36	1.4	40	2600	70	4.3	11.1
		2.8	Furrow-R	39	1.5	60	2600	85	3.3	17.0
		2.8	Furrow-C	39	1.5	60	2600	70	4.0	14.4
			Sprinkler							
Sugar Beets	2.5	3.0	Furrow-R	20	0.8	22	2500	85	3.5	13.1
			Furrow-C	20	0.8	22	2500	70	4.3	11.1
			Sprinkler							
Small Grain	2.5	3.0	Border	-	0.0018	60	2600	60	5.0	6.5
		3.0	Furrow-R	26	1.0	30	2600	85	3.5	13.1
		3.0	Furrow-C	26	1.0	30	2600	70	4.3	11.1
		3.0	Furrow-R	36	1.4	40	2600	85	3.5	13.1
		3.0	Furrow-C	36	1.4	40	2600	70	4.3	11.1
			Sprinkler							
	R = Reuse		C = Cutback							

U.S. DEPT. OF AGRICULTURE
SOIL CONSERVATION SERVICE

IRRIGATION DESIGN

GENERAL SOILS DESCRIPTION: Moderately deep soils with silt loam, clay loam or silty clay loam surface layers and subsoils with predominantly moderately slow permeability.

GROUP NO 4

(Intake Family 0.3)

Sheet 2 of 3
Date 1975

CROPS	NORMAL IRRIGATION DEPTH feet	NET MOISTURE TO BE REPLACED EACH IRRIGATION inches	ADAPTED CONSERVATION IRRIGATION METHODS	MAXIMUM SIZE STREAM FOR FURROWS OR CORRUGATIONS g.p.m.	UNIT STREAM BORDERS OR CONTOUR DITCH C.F.S. PER 100 SQ.FT. FURROWS OR CORRUGATIONS G.P.M./100' OF LENGTH c.f.s. or g.p.m.	MAXIMUM BORDER WIDTH feet NORMAL FURROW OR CORRUGATION SPACING inches ft or in.	MAXIMUM LENGTH OF RUN feet	EST FIELD EFF. %	GROSS WATER USED inches	ESTIMATED TIME REQUIRED hours
1	2	3	4	5	6	7	8	9	10	11
		SLOPE GROUP 0.26 TO 0.55% (DESIGN SLOPE 0.4%)								
Alfalfa or Grass	2.5	3.0	Border	–	0.0021*	60	2600	50	6.0	6.7
			Sprinkler							
Corn, Sorghum or Beans	2.5	3.0	Furrow-R	26	1.0	30	2600	85	3.5	13.1
		3.0	Furrow-C	26	1.0	30	2600	70	4.3	11.1
		3.0	Furrow-R	30	1.4	40	2150	85	3.5	13.1
		3.0	Furrow-C	30	1.4	40	2150	70	4.3	11.1
		2.7	Furrow-R	30	1.4	60	2150	85	3.2	17.7
		2.7	Furrow-C	30	1.4	60	2150	70	3.9	15.0
			Sprinkler							
Sugar Beets	2.5	3.0	Furrow-R	20	0.8	22	2500	85	3.5	13.1
		3.0	Furrow-C	20	0.8	22	2500	70	4.3	11.1
			Sprinkler							
Small Grain	2.5	3.0	Border	–	0.0021*	60	2600	50	6.0	6.7
		3.0	Furrow-R	26	1.0	30	2600	85	3.5	13.1
		3.0	Furrow-C	26	1.0	30	2600	70	4.3	11.1
		3.0	Furrow-R	30	1.4	40	2150	85	3.5	13.1
		3.0	Furrow-C	30	1.4	40	2150	70	4.3	11.1
			Sprinkler							
* * * * * * *	* * * *	* * * *	* * * * * * *	* * * *	* * * * *	* * * *	* * * *	* *	* * * *	* * * * *
		SLOPE GROUP 0.56 TO 1.0% (DESIGN SLOPE 0.7%)								
Alfalfa or Grass	2.5	3.0	Border	–	0.0021*	50	2600	50	6.0	6.7
		3.0	Corrugation	8	0.7	20	1150	60	5.0	11.7
			Sprinkler							
Corn, Sorghum or Beans	2.5	3.0	Furrow-R	17	1.0	30	1700	80	3.8	13.8
		3.0	Furrow-C	17	1.0	30	1700	65	4.6	11.7
		3.0	Furrow-R	17	1.3	40	1310	80	3.8	14.2
		3.0	Furrow-C	17	1.3	40	1310	65	4.6	12.0
		2.5	Furrow-R	17	1.3	60	1310	80	3.1	17.7
		2.5	Furrow-C	17	1.3	60	1310	65	3.8	15.0
		3.0	Contour Furrow (Refer to 30" or 40" furrow with design slope 0.4%)							
			Sprinkler							
Sugar Beets	2.5	3.0	Furrow-R	17	0.8	22	2130	80	3.8	11.7
			Furrow-C	17	0.8	22	2130	65	4.6	11.7
			Sprinkler							
Small Grain	2.5	3.0	Border	–	0.0021*	50	2600	50	6.0	6.7
		3.0	Furrow-R	17	1.0	30	1700	80	3.8	13.8
		3.0	Furrow-C	17	1.0	30	1700	65	4.6	11.7
		3.0	Furrow-R	17	1.3	40	1310	80	3.8	14.2
		3.0	Furrow-C	17	1.3	40	1310	65	4.6	12.0
		3.0	Corrugation	8	0.7	20	1150	60	5.0	11.7
			Sprinkler							

R = Reuse C = Cutback

*Corrugations are required to provide adequate spread of border stream

U.S. DEPT. OF AGRICULTURE
SOIL CONSERVATION SERVICE

IRRIGATION DESIGN

GENERAL SOILS DESCRIPTION Moderately deep soils with silt loam, clay loam or silty clay loam surface layers and subsoils with predominantly moderately slow permeability.

GROUP NO 4

(Intake Family 0.3)

Sheet 3 of 3
Date 1975

CROPS	NORMAL IRRIGATION DEPTH	NET MOISTURE TO BE REPLACED EACH IRRIGATION	ADAPTED CONSERVATION IRRIGATION METHODS	MAXIMUM SIZE STREAM FOR FURROWS OR CORRUGATIONS	UNIT STREAM BORDERS OR CONTOUR DITCH C.F.S. PER 100 SQ FT. FURROWS OR CORRUGATIONS G.P.M./100' OF LENGTH	MAXIMUM BORDER WIDTH feet NORMAL FURROW OR CORRUGATION SPACING inches	MAXIMUM LENGTH OF RUN	EST. FIELD EFF.	GROSS WATER USED	ESTIMATED TIME REQUIRED
	feet	inches		g.p.m.	c.f.s. or g.p.m	ft. or in.	feet	%	inches	hours
1	2	3	4	5	6	7	8	9	10	11
SLOPE GROUP 1.1 TO 2.0% (DESIGN SLOPE 1.5%)										
Alfalfa, Grass or Small Grain	2.5	3.0	Corrugation Sprinkler	8	0.7	20	1140	60	5.0	1.7
Corn, Sorghum or Beans	2.5	3.0	Contour Furrow (Refer to 30" or 40" furrow with design slope 0.4%) Sprinkler							
Sugar Beets	2.5	3.0	Sprinkler							
* *										
SLOPE GROUP 2.1 TO 4.0% (DESIGN SLOPE 3.0%)(Contour furrow or sprinkler with terraces)										
Alfalfa, Beets or Small Grain	2.5	3.0	Sprinkler							
Corn, Sorghum or Beans	2.5	3.0	Contour Furrow (Refer to 30" or 40" furrow with design slope 0.4%) Sprinkler							
Grass	2.5	3.0	Corrugation Sprinkler	4	0.7	20	570	60	5.0	11.7
* *										
SLOPE GROUP 4.1 TO 8.0% (DESIGN SLOPE GROUP 6.0%)										
Irrigation not recommended.										

IRRIGATION DESIGN

U.S. DEPT. OF AGRICULTURE
SOIL CONSERVATION SERVICE

GENERAL SOILS DESCRIPTION: Deep soils with silt loam, loam or clay loam surface layers and subsoils having moderate to moderately slow permeability. (Intake Family 0.5)

GROUP NO 5

Sheet 1 of 3
Date 1975

CROPS	NORMAL IRRIGATION DEPTH (feet)	NET MOISTURE TO BE REPLACED EACH IRRIGATION (inches)	ADAPTED CONSERVATION IRRIGATION METHODS	MAXIMUM SIZE STREAM FOR FURROWS OR CORRUGATIONS (g.p.m)	UNIT STREAM BORDERS OR CONTOUR DITCH C.F.S. PER 100 SQ.FT. FURROWS OR CORRUGATIONS G.P.M./100' OF LENGTH (c.f.s. or g.p.m.)	MAXIMUM BORDER WIDTH feet NORMAL FURROW OR CORRUGATION SPACING inches (ft. or in.)	MAXIMUM LENGTH OF RUN (feet)	EST. FIELD EFF. (%)	GROSS WATER USED (inches)	ESTIMATED TIME REQUIRED (hours)
1	2	3	4	5	6	7	8	9	10	11
		SLOPE	GROUP LESS THAN 0.05%		(DESIGN SLOPE LEVEL)					
Alfalfa	4.0	5.0	Level Border	-	0.0039	100	1400	80	6.2	3.7
			Sprinkler							
Corn, Sorghum Beans, Grass or Small Grain	3.0	4.0	Level Border	-	0.0050	100	1200	80	5.0	2.3
			Sprinkler							
		SLOPE	GROUP 0.05 TO 0.14%		(DESIGN SLOPE 0.1%)					
Alfalfa	4.0	5.0	Border	-	0.0023	60	2600	70	7.1	7.2
			Sprinkler							
Corn, Sorghum or Beans	3.0	4.0	Furrow-R	30	1.5	30	2000	85	4.7	12.0
		4.0	Furrow-C	30	1.5	30	2000	70	5.7	10.2
		4.0	Furrow-R	50	2.0	40	2500	85	4.7	12.0
		4.0	Furrow-C	50	2.0	40	2500	70	5.7	10.2
		3.8	Furrow-R	40	2.3	60	1740	85	4.5	15.2
		3.8	Furrow-C	40	2.3	60	1740	70	5.4	12.9
			Sprinkler							
Sugar Beets	3.0	4.0	Furrow-R	20	1.1	22	1820	85	4.7	12.0
		4.0	Furrow-C	20	1.1	22	1820	70	5.7	10.2
			Sprinkler							
Small Grain	3.0	4.0	Border	-	0.0026	60	2600	70	5.7	6.2
		4.0	Furrow-R	30	1.5	30	2000	85	4.7	12.0
		4.0	Furrow-C	30	1.5	30	2000	70	5.7	10.2
		4.0	Furrow-R	50	2.0	40	2500	85	4.7	12.0
		4.0	Furrow-C	50	2.0	40	2500	70	5.7	10.2
			Sprinkler							
Grass	3.0	4.0	Border	-	0.0026	60	2600	70	5.7	6.2
			Sprinkler							
		SLOPE	GROUP 0.15 TO 0.25%		(DESIGN SLOPE 0.2%)					
Alfalfa	4.0	5.0	Border	-	0.0024	60	2600	65	7.7	7.5
			Sprinkler							
Corn, Sorghum or Beans	3.0	4.0	Furrow-R	30	1.5	30	2000	85	4.7	12.0
		4.0	Furrow-C	30	1.5	30	2000	70	5.7	10.2
		4.0	Furrow-R	50	2.0	40	2500	85	4.7	12.0
		4.0	Furrow-C	50	2.0	40	2500	70	5.7	10.2
		3.8	Furrow-R	40	2.2	60	1820	85	4.5	15.5
		3.8	Furrow-C	40	2.2	60	1820	70	5.4	13.1
			Sprinkler							
Sugar Beets	3.0	4.0	Furrow-R	20	1.1	22	1820	85	4.7	12.0
		4.0	Furrow-C	20	1.1	22	1820	70	5.7	10.2
			Sprinkler							
Small Grain	3.0	4.0	Border	-	0.0026	60	2600	65	6.2	5.5
		4.0	Furrow-R	30	1.5	30	2000	85	4.7	12.0
		4.0	Furrow-C	30	1.5	30	2000	70	5.7	10.2
		4.0	Furrow-R	50	2.0	40	2500	85	4.7	12.0
		4.0	Furrow-C	50	2.0	40	2500	70	5.7	10.2
			Sprinkler							
Grass	3.0	4.0	Border	-	0.0026	60	2600	65	6.2	5.5
			Sprinkler							
R = Reuse	C = Cutback									

U.S. DEPT. OF AGRICULTURE
SOIL CONSERVATION SERVICE

IRRIGATION DESIGN

GENERAL SOILS DESCRIPTION. Deep soils with silt loam, loam or clay loam surface layers and subsoils having moderate to moderately slow permeability. (Intake Family 0.5)

GROUP NO 5

Sheet 2 of 3
Date 1975

CROPS	NORMAL IRRIGATION DEPTH feet	NET MOISTURE TO BE REPLACED EACH IRRIGATION inches	ADAPTED CONSERVATION IRRIGATION METHODS	MAXIMUM SIZE STREAM FOR FURROWS OR CORRUGATIONS g.p.m.	UNIT STREAM BORDERS OR CONTOUR DITCH C.F.S. PER 100 SQ.FT. FURROWS OR CORRUGATIONS G.P.M./100' OF LENGTH c.f.s. or g.p.m.	MAXIMUM BORDER WIDTH feet NORMAL FURROW OR CORRUGATION SPACING inches ft. or in.	MAXIMUM LENGTH OF RUN feet	EST. FIELD EFF. %	GROSS WATER USED inches	ESTIMATED TIME REQUIRED hours
1	2	3	4	5	6	7	8	9	10	11
		SLOPE GROUP 0.26 TO 0.55% (DESIGN SLOPE 0.4%)								
Alfalfa	4.0	5.0	Border	-	0.0026	60	2600	60	8.3	7.5
			Sprinkler							
Corn, Sorghum or Beans	3.0	4.0	Furrow-R	30	1.5	30	2000	85	4.7	12.0
		4.0	Furrow-C	30	1.5	30	2000	70	5.7	10.2
		4.0	Furrow-R	30	2.0	40	1500	85	4.7	12.0
		4.0	Furrow-C	30	2.0	40	1500	70	5.7	10.2
		3.7	Furrow-R	30	2.1	60	1430	85	4.4	15.8
		3.7	Furrow-C	30	2.1	60	1430	70	5.3	13.4
			Sprinkler							
Sugar Beets	3.0	4.0	Furrow-R	20	1.1	22	1820	85	4.7	12.0
			Furrow-C	20	1.1	22	1820	70	5.7	10.2
			Sprinkler							
Small Grain	3.0	4.0	Border	-	0.0028	50	2550	60	6.7	5.5
		4.0	Furrow-R	30	1.5	30	2000	85	4.7	12.0
		4.0	Furrow-C	30	1.5	30	2000	70	5.7	10.2
		4.0	Furrow-R	30	2.0	40	1500	85	4.7	12.0
		4.0	Furrow-C	30	2.0	40	1500	70	5.7	10.2
			Sprinkler							
Grass	3.0	4.0	Border	-	0.0028	50	2550	60	6.7	5.5
			Sprinkler							
* * * * * *	* * * *	* * * *	* * * * *	* * * *	* * * *	* * * *	* * *	* *	* * * *	* * * *
		SLOPE GROUP 0.56 TO 1.0% (DESIGN SLOPE 0.7%)								
Alfalfa	4.0	5.0	Border	-	0.0028*	50	2550	55	9.1	7.5
	3.0	4.0	Corrugation	8	1.0	20	800	60	6.7	10.2
			Sprinkler							
Corn, Sorghum or Beans	3.0	4.0	Furrow-R	17	1.5	30	1130	80	5.0	12.9
		4.0	Furrow-C	17	1.5	30	1130	65	6.2	10.9
		4.0	Furrow-R	17	1.9	40	900	80	5.0	13.9
		4.0	Furrow-C	17	1.9	40	900	65	6.2	11.8
		3.4	Furrow-R	17	1.9	60	900	80	4.3	16.3
		3.4	Furrow-C	17	1.9	60	900	65	5.3	13.8
		4.0	Contour Furrow (Refer to 30" or 40" furrow with design slope 0.4%)							
			Sprinkler							
Sugar Beets	3.0	4.0	Furrow-R	17	1.1	22	1550	80	5.0	12.0
			Furrow-C	17	1.1	22	1550	65	6.2	10.2
			Sprinkler							
Small Grain	3.0	4.0	Border	-	0.0032	50	2300	55	7.3	5.5
		4.0	Furrow-R	17	1.5	30	1130	80	5.0	12.9
		4.0	Furrow-C	17	1.5	30	1130	65	6.2	10.9
		4.0	Furrow-R	17	1.9	40	900	80	5.0	13.9
		4.0	Furrow-C	17	1.9	40	900	65	6.2	11.8
		4.0	Corrugation	8	1.0	20	800	60	6.7	10.2
			Sprinkler							
Grass	3.0	4.0	Border	-	0.0032	50	2300	55	7.3	5.5
		4.0	Corrugation	8	1.0	20	800	60	6.7	10.2
			Sprinkler							

R = Reuse C = Cutback

* Corrugations are required to provide adequate spread of border stream

IRRIGATION DESIGN

U.S. DEPT. OF AGRICULTURE
SOIL CONSERVATION SERVICE

GENERAL SOILS DESCRIPTION: Deep soils with silt loam, loam or clay loam surface layers and subsoils having moderate to moderately slow permeability. (Intake Family 0.5)

GROUP NO 5

Sheet 3 of 3
Date 1975

CROPS	NORMAL IRRIGATION DEPTH feet	NET MOISTURE TO BE REPLACED EACH IRRIGATION inches	ADAPTED CONSERVATION IRRIGATION METHODS	MAXIMUM SIZE STREAM FOR FURROWS OR CORRUGATIONS g.p.m.	UNIT STREAM BORDERS OR CONTOUR DITCH C.F.S. PER 100 SQ.FT. FURROWS OR CORRUGATIONS G.P.M./100' OF LENGTH c.f.s or g.p.m	MAXIMUM BORDER WIDTH feet NORMAL FURROW OR CORRUGATION SPACING inches ft. or in.	MAXIMUM LENGTH OF RUN feet	EST. FIELD EFF. %	GROSS WATER USED inches	ESTIMATED TIME REQUIRED hours
1	2	3	4	5	6	7	8	9	10	11
SLOPE GROUP 1.1 TO 2.0% (DESIGN SLOPE 1.5%)										
Alfalfa	4.0	5.0	Border	–	0.0034*	40	1300	50	8.0	5.5
		4.0	Corrugation	8	1.0	20	800	60	6.7	10.2
			Sprinkler							
Corn, Sorghum or Beans	3.0	4.0	Contour Furrow (Refer to 30" or 40" furrow with design slope 0.4%)							
			Sprinkler							
Small Grain or Grass	3.0	4.0	Border	–	0.0034*	40	1300	50	8.0	5.5
		4.0	Corrugation	8	1.0	20	800	60	6.7	10.2
			Sprinkler							
Sugar Beets	3.0	4.0	Sprinkler							
* * * * * * *	* * * * *	* * * *	* * * * * *	* * * *	* * * *	* * * *	* * *	* * *	* * * *	* * * *
SLOPE GROUP 2.1 TO 4.0% (DESIGN SLOPE 3.0%)(Contour furrow or sprinkler with terraces)										
Alfalfa	4.0	5.0	Sprinkler							
Corn, Sorghum or Beans	3.0	4.0	Contour Furrow (Refer to 30" or 40" furrow with design slope 0.4%)							
			Sprinkler							
Small Grain or S. Beets	3.0	4.0	Sprinkler							
Grass	3.0	4.0	Corrugation	4	1.0	20	400	60	6.7	10.2
			Sprinkler							
* * * * * * *	* * * * *	* * * *	* * * * * *	* * * *	* * * *	* * * *	* * *	* * *	* * * *	* * * *
SLOPE GROUP 4.1 TO 8.0% (DESIGN SLOPE 6.0%)(Sprinkler with terraces)										
Alfalfa	4.0	5.0	Sprinkler							
Corn, Sorghum Beans, Grass or Small Grain	3.0	4.0	Sprinkler							

* Corrugations are required to provide adequate spread for border stream

IG Notice KA-3, 10-14-77

U.S. DEPT. OF AGRICULTURE
SOIL CONSERVATION SERVICE

IRRIGATION DESIGN

GENERAL SOILS DESCRIPTION: Moderately deep soils with silt loam, loam or clay loam surface layers and subsoils having moderate to moderately slow permeability. (Intake Family 0.5)

GROUP NO 6

Sheet 1 of 3

Date 1975

CROPS	NORMAL IRRIGATION DEPTH feet	NET MOISTURE TO BE REPLACED EACH IRRIGATION inches	ADAPTED CONSERVATION IRRIGATION METHODS	MAXIMUM SIZE STREAM FOR FURROWS OR CORRUGATIONS g.p.m.	UNIT STREAM BORDERS OR CONTOUR DITCH C.F.S. PER 100 SQ.FT. FURROWS OR CORRUGATIONS G P M./100' OF LENGTH c.f.s. or g p m	MAXIMUM BORDER WIDTH feet NORMAL FURROW OR CORRUGATION SPACING inches ft. or in	MAXIMUM LENGTH OF RUN feet	EST. FIELD EFF. %	GROSS WATER USED inches	ESTIMATED TIME REQUIRED hours
1	2	3	4	5	6	7	8	9	10	11
		SLOPE GROUP LESS THAN 0.05% (DESIGN SLOPE LEVEL)								
Alfalfa, Grass	3.0	3.5	Level Border	-	0.0062	100	1100	80	4.4	1.6
Corn, Sorghum			Sprinkler							
Beans, Sm. Gr.										
* * * * * * *	* * * *	* * * *	* * * * * *	* * * *	* * * * *	* * * *	* * *	* *	* * *	* * *
		SLOPE GROUP 0.05 TO 0.14% (DESIGN SLOPE 0.1%)								
Alfalfa or Grass	3.0	3.5	Border	-	0.0028	60	2550	70	5.0	4.3
			Sprinkler							
Corn, Sorghum or Beans	3.0	3.5	Furrow-R	30	1.6	30	1900	85	4.1	10.0
		3.5	Furrow-C	30	1.6	30	1900	70	5.0	8.5
		3.5	Furrow-R	50	2.1	40	2400	85	4.1	10.0
		3.5	Furrow-C	50	2.1	40	2400	70	5.0	8.5
		3.2	Furrow-R	40	2.2	60	1820	85	3.8	13.0
		3.2	Furrow-C	40	2.2	60	1820	70	4.6	11.0
			Sprinkler							
Sugar Beets	3.0	3.5	Furrow-R	20	1.2	22	1670	85	4.1	10.0
		3.5	Furrow-C	20	1.2	22	1670	70	5.0	8.5
			Sprinkler							
Small Grain	3.0	3.5	Border	-	0.0028	60	2550	70	5.0	4.3
		3.5	Furrow-R	30	1.6	30	1880	85	4.1	10.0
		3.5	Furrow-C	30	1.6	30	1880	70	5.0	8.5
		3.5	Furrow-R	50	2.1	40	2380	85	4.1	10.0
		3.5	Furrow-C	50	2.1	40	2380	70	5.0	8.5
			Sprinkler							
* * * * * * *	* * * *	* * * *	* * * * * *	* * * *	* * * * *	* * * *	* * *	* *	* * *	* * *
		SLOPE GROUP 0.15 TO 0.25% (DESIGN SLOPE 0.2%)								
Alfalfa or Grass	3.0	3.5	Border	-	0.0028	60	2550	65	5.4	4.5
			Sprinkler							
Corn, Sorghum or Beans	3.0	3.5	Furrow-R	30	1.6	30	1880	85	4.1	10.0
		3.5	Furrow-C	30	1.6	30	1880	70	5.0	8.5
		3.5	Furrow-R	50	2.1	40	2380	85	4.1	10.0
		3.5	Furrow-C	50	2.1	40	2380	70	5.0	8.5
		3.2	Furrow-R	40	2.2	60	1820	85	3.8	13.2
		3.2	Furrow-C	40	2.2	60	1820	70	4.6	11.2
			Sprinkler							
Sugar Beets	3.0	3.5	Furrow-R	20	1.2	22	1670	85	4.1	10.0
			Furrow-C	20	1.2	22	1670	70	5.0	8.5
			Sprinkler							
Small Grain	3.0	3.5	Border	-	0.0028	60	2550	65	5.4	4.5
		3.5	Furrow-R	30	1.6	30	1880	85	4.1	10.0
		3.5	Furrow-C	30	1.6	30	1880	70	5.0	8.5
		3.5	Furrow-R	50	2.1	40	2380	85	4.1	10.0
		3.5	Furrow-C	50	2.1	40	2380	70	5.0	8.5
			Sprinkler							
R = Reuse	C = Cutback									

IRRIGATION DESIGN

U.S. DEPT. OF AGRICULTURE
SOIL CONSERVATION SERVICE

GENERAL SOILS DESCRIPTION: Moderately deep soils with silt loam, loam or clay loam surface layers and subsoils having moderate to moderately slow permeability. (Intake Family 0.5)

GROUP NO 6

Sheet 2 of 3
Date 1975

CROPS	NORMAL IRRIGATION DEPTH (feet)	NET MOISTURE TO BE REPLACED EACH IRRIGATION (inches)	ADAPTED CONSERVATION IRRIGATION METHODS	MAXIMUM SIZE STREAM FOR FURROWS OR CORRUGATIONS (g.p.m)	UNIT STREAM BORDERS OR CONTOUR DITCH C.F.S. PER 100 SQ.FT. FURROWS OR CORRUGATIONS G.P.M./100' OF LENGTH (c.f.s. or g p.m)	MAXIMUM BORDER WIDTH feet NORMAL FURROW OR CORRUGATION SPACING inches (ft. or in.)	MAXIMUM LENGTH OF RUN (feet)	EST. FIELD EFF. (%)	GROSS WATER USED (inches)	ESTIMATED TIME REQUIRED (hours)
1	2	3	4	5	6	7	8	9	10	11
		SLOPE GROUP 0.26 TO 0.55% (DESIGN SLOPE 0.4%)								
Alfalfa or	3.0	3.5	Border	–	0.0030	60	2460	60	5.8	4.6
Grass			Sprinkler							
Corn, Sorghum	3.0	3.5	Furrow-R	30	1.6	30	1880	85	4.1	10.0
or Beans		3.5	Furrow-C	30	1.6	30	1880	70	5.0	8.5
		3.5	Furrow-R	30	2.1	40	1430	85	4.1	10.3
		3.5	Furrow-C	30	2.1	40	1430	70	5.0	8.7
		3.1	Furrow-R	30	2.1	60	1430	85	3.7	13.6
		3.1	Furrow-C	30	2.1	60	1430	70	4.4	11.5
			Sprinkler							
Sugar Beets	3.0	3.5	Furrow-R	20	1.2	22	1670	85	4.1	10.0
		3.5	Furrow-C	20	1.2	22	1670	70	5.0	8.5
			Sprinkler							
Small Grain	3.0	3.5	Border	–	0.0030	60	2460	60	5.8	4.6
		3.5	Furrow-R	30	1.6	30	1880	85	4.1	10.0
		3.5	Furrow-C	30	1.6	30	1880	70	5.0	8.5
		3.5	Furrow-R	30	2.1	40	1430	85	4.1	10.3
		3.5	Furrow-C	30	2.1	40	1430	70	5.0	8.7
			Sprinkler							
		SLOPE GROUP 0.56 TO 1.0% (DESIGN SLOPE 0.7%)								
Alfalfa or	3.0	3.5	Border	–	0.0033*	50	2200	55	6.4	4.6
Grass		3.5	Corrugation	8	1.1	20	730	60	5.8	8.5
			Sprinkler							
Corn, Sorghum	3.0	3.5	Furrow-R	17	1.6	30	1070	80	4.4	10.0
or Beans		3.5	Furrow-C	17	1.6	30	1070	65	5.4	8.5
		3.5	Furrow-R	17	1.8	40	950	80	4.4	11.3
		3.5	Furrow-C	17	1.8	40	950	65	5.4	9.6
		2.8	Furrow-R	17	1.9	60	900	80	3.5	13.6
		2.8	Furrow-C	17	1.9	60	900	65	4.3	11.5
		3.5	Contour Furrow (Refer to 30" or 40" furrow with design slope 0.4%)							
			Sprinkler							
Sugar Beets	3.0	3.5	Furrow-R	17	1.2	22	1420	80	4.4	8.5
			Furrow-C	17	1.2	22	1420	65	5.4	8.5
			Sprinkler							
Small Grain	3.0	3.5	Border	–	0.0033*	50	2200	55	6.4	4.6
		3.5	Furrow-R	17	1.6	30	1070	80	4.4	10.0
		3.5	Furrow-C	17	1.6	30	1070	65	5.4	8.5
		3.5	Furrow-R	17	1.8	40	950	80	4.4	11.3
		3.5	Furrow-C	17	1.8	40	950	65	5.4	9.6
		3.5	Corrugation	8	1.1	20	730	60	5.8	8.5
			Sprinkler							

R = Reuse C = Cutback

* Corrugations are required to provide adequate spread of border stream

IRRIGATION DESIGN

U.S. DEPT. OF AGRICULTURE
SOIL CONSERVATION SERVICE

GENERAL SOILS DESCRIPTION: Moderately deep soils with silt loam, loam or clay loam surface layers and subsoils having moderate to moderately slow permeability. (Intake Family 0.5)

GROUP NO 6

Date 1975

CROPS	NORMAL IRRIGATION DEPTH feet	NET MOISTURE TO BE REPLACED EACH IRRIGATION inches	ADAPTED CONSERVATION IRRIGATION METHODS	MAXIMUM SIZE STREAM FOR FURROWS OR CORRUGATIONS g.p.m.	UNIT STREAM BORDERS OR CONTOUR DITCH C.F.S. PER 100 SQ FT. FURROWS OR CORRUGATIONS G.P.M./100' OF LENGTH c.f.s. or g.p.m.	MAXIMUM BORDER WIDTH feet NORMAL FURROW OR CORRUGATION SPACING inches ft. or in.	MAXIMUM LENGTH OF RUN feet	EST. FIELD EFF. %	GROSS WATER USED inches	ESTIMATED TIME REQUIRED hours
1	2	3	4	5	6	7	8	9	10	11
SLOPE GROUP 1.1 TO 2.0% (DESIGN SLOPE 1.5%)										
Alfalfa, Grass	3.0	3.5	Border	-	0.0036*	40	1200	50	7.0	4.6
or Small Grain		3.0	Corrugation	8	1.1	20	730	60	5.0	7.0
			Sprinkler							
Corn, Sorghum	3.0	3.5	Contour Furrow (Refer to 30" or 40" furrow with design slope 0.4%)							
or Beans			Sprinkler							
Sugar Beets	3.0	3.5	Sprinkler							
* *										
SLOPE GROUP 2.1 TO 4.0% (DESIGN SLOPE 3.0%)(Contour furrow or sprinkler with terraces)										
Alfalfa	2.5	3.0	Sprinkler							
Sugar Beets or										
Small Grain										
Corn, Sorghum	2.5	3.0	Contour Furrow (Refer to 30" or 40" furrow with design slope 0.4%)							
or Beans			Sprinkler							
Grass	2.5	3.0	Corrugation	4	1.1	20	360	60	5.0	7.0
			Sprinkler							
* *										
SLOPE GROUP 4.1 TO 8.0% (DESIGN SLOPE 6.0%)(Sprinkler with terraces)										
Alfalfa, Grass	2.5	3.0	Sprinkler							
Corn, Sorghum										
Small Grain										
or Beans										

IRRIGATION DESIGN

U.S. DEPT. OF AGRICULTURE
SOIL CONSERVATION SERVICE

GENERAL SOILS DESCRIPTION Deep soils with silt loam, loam or very fine sandy loam surface layers and moderately permeable, medium textured subsoils. (Intake Family 1.0)

GROUP NO 7

Sheet 1 of 3
Date 1975

CROPS	NORMAL IRRIGATION DEPTH	NET MOISTURE TO BE REPLACED EACH IRRIGATION	ADAPTED CONSERVATION IRRIGATION METHODS	MAXIMUM SIZE STREAM FOR FURROWS OR CORRUGATIONS	UNIT STREAM BORDERS OR CONTOUR DITCH C.F.S. PER 100 SQ.FT. FURROWS OR CORRUGATIONS G.P.M./100' OF LENGTH	MAXIMUM BORDER WIDTH feet NORMAL FURROW OR CORRUGATION SPACING inches	MAXIMUM LENGTH OF RUN	EST. FIELD EFF.	GROSS WATER USED	ESTIMATED TIME REQUIRED
	feet	inches		g.p.m	c.f.s. or g.p.m	ft. or in.	feet	%	inches	hours
1	2	3	4	5	6	7	8	9	10	11
		SLOPE GROUP LESS THAN 0.05% (DESIGN SLOPE LEVEL)								
Alfalfa	5.0	5.0	Level Border	-	0.0080	60	850	80	6.3	1.8
			Sprinkler							
Corn, Sorghum Beans, Grass or Small Grain	3.0	3.0	Level Border	-	0.0160	40	650	80	3.8	0.5
			Sprinkler							
* * * * * *	* * * *	* * * *	* * * * *	* * * *	* * * * *	* * *	* * *	* *	* * *	* * * *
		SLOPE GROUP 0.05 TO 0.14% (DESIGN SLOPE 0.1%)								
Alfalfa	5.0	5.0	Border	-	0.0048	60	1600	75	6.7	3.3
			Sprinkler							
Corn, Sorghum or Beans	3.0	3.0	Furrow-R	30	2.8	30	1080	85	3.5	5.0
		3.0	Furrow-C	30	2.8	30	1080	70	4.3	4.2
		3.0	Furrow-R	50	3.6	40	1400	85	3.5	5.2
		3.0	Furrow-C	50	3.6	40	1400	70	4.3	4.4
		2.5	Furrow-R	40	3.4	60	1180	85	2.9	6.7
		2.5	Furrow-C	40	3.4	60	1180	70	3.6	5.7
			Sprinkler							
Sugar Beets	3.0	3.0	Furrow-R	20	2.1	22	950	85	3.5	5.0
		3.0	Furrow-C	20	2.1	22	950	70	4.3	4.2
			Sprinkler							
Small Grain	3.0	3.0	Border	-	0.0063	60	1200	75	4.0	1.5
		3.0	Furrow-R	30	2.8	30	1080	85	3.5	5.0
		3.0	Furrow-C	30	2.8	30	1080	70	4.3	4.2
		3.0	Furrow-R	50	3.6	40	1400	85	3.5	5.2
		3.0	Furrow-C	50	3.6	40	1400	70	4.3	4.4
			Sprinkler							
Grass	3.0	3.0	Border	-	0.0063	60	1200	75	4.0	1.5
			Sprinkler							
* * * * * *	* * * *	* * * *	* * * * * *	* * * *	* * * * *	* * * *	* * *	* *	* * * *	* * * *
		SLOPE GROUP 0.15 TO 0.25% (DESIGN SLOPE 0.2%)								
Alfalfa	5.0	5.0	Border	-	0.0048	60	1600	75	6.7	3.3
			Sprinkler							
Corn, Sorghum or Beans	3.0	3.0	Furrow-R	30	2.8	30	1080	85	3.5	5.0
		3.0	Furrow-C	30	2.8	30	1080	70	4.3	4.2
		3.0	Furrow-R	50	3.5	40	1430	85	3.5	5.3
		3.0	Furrow-C	50	3.5	40	1430	70	4.3	4.5
		2.5	Furrow-R	40	3.4	60	1180	85	2.9	6.7
		2.5	Furrow-C	40	3.4	60	1180	70	3.6	5.7
			Sprinkler							
Sugar Beets	3.0	3.0	Furrow-R	20	2.1	22	950	85	3.5	5.0
		3.0	Furrow-C	20	2.1	22	950	70	4.3	4.2
			Sprinkler							
Small Grain	3.0	3.0	Border	-	0.0062	60	1210	70	4.3	1.6
		3.0	Furrow-R	30	2.8	30	1080	85	3.5	5.0
		3.0	Furrow-C	30	2.8	30	1080	70	4.3	4.2
		3.0	Furrow-R	50	3.5	40	1430	85	3.5	5.3
		3.0	Furrow-C	50	3.5	40	1430	70	4.3	4.5
			Sprinkler							
Grass	3.0	3.0	Border	-	0.0062	60	1210	70	4.3	1.6
			Sprinkler							
R = Reuse	C = Cutback									

IG Notice KA-3, 10-14-77

IRRIGATION DESIGN

U.S. DEPT. OF AGRICULTURE
SOIL CONSERVATION SERVICE

GENERAL SOILS DESCRIPTION: Deep soils with silt loam, loam or very fine sandy loam surface layers and moderately permeable, medium textured subsoils.

GROUP NO 7

(Intake Family 1.0)

Sheet 2 of 3
Date 1975

CROPS	NORMAL IRRIGATION DEPTH	NET MOISTURE TO BE REPLACED EACH IRRIGATION	ADAPTED CONSERVATION IRRIGATION METHODS	MAXIMUM SIZE STREAM FOR FURROWS OR CORRUGATIONS	UNIT STREAM BORDERS OR CONTOUR DITCH C.F.S. PER 100 SQ.FT. / FURROWS OR CORRUGATIONS G.P.M./100' OF LENGTH	MAXIMUM BORDER WIDTH feet / NORMAL FURROW OR CORRUGATION SPACING inches	MAXIMUM LENGTH OF RUN	EST. FIELD EFF.	GROSS WATER USED	ESTIMATED TIME REQUIRED
	feet	inches		g.p.m.	c.f.s. or g.p.m.	ft. or in.	feet	%	inches	hours
1	2	3	4	5	6	7	8	9	10	11
		SLOPE GROUP 0.26 TO 0.55% (DESIGN SLOPE 0.4%)								
Alfalfa	5.0	5.0	Border	-	0.0048	60	1550	70	7.1	3.6
			Sprinkler							
Corn, Sorghum or Beans	3.0	3.0	Furrow-R	30	2.8	30	1080	85	3.5	5.0
		3.0	Furrow-C	30	2.8	30	1080	70	4.3	4.2
		3.0	Furrow-R	30	3.2	40	940	85	3.5	5.7
		3.0	Furrow-C	30	3.2	40	940	70	4.3	4.8
		2.3	Furrow-R	30	3.2	60	940	85	2.7	6.7
		2.3	Furrow-C	30	3.2	60	940	70	3.3	5.7
			Sprinkler							
Sugar Beets	3.0	3.0	Furrow-R	20	2.1	22	950	85	3.5	5.0
		3.0	Furrow-C	20	2.1	22	950	70	4.3	4.2
			Sprinkler							
Small Grain	3.0	3.0	Border	-	0.0062	60	1210	65	4.6	1.8
		3.0	Furrow-R	30	2.8	30	1080	85	3.5	5.0
		3.0	Furrow-C	30	2.8	30	1080	70	4.3	4.2
		3.0	Furrow-R	30	3.2	40	940	85	3.5	5.7
		3.0	Furrow-C	30	3.2	40	940	70	4.3	4.9
			Sprinkler							
Grass	3.0	3.0	Border	-	0.0062	60	1210	65	4.6	1.8
			Sprinkler							
* * * * * * *	* * * * *	* * * *	* * * * * * *	* * * *	* * * *	* * * *	* * * *	* *	* * * *	* * * *
		SLOPE GROUP 0.56 TO 1.0% (DESIGN SLOPE 0.7%)								
Alfalfa	5.0	5.0	Border	-	0.0050	50	1500	65	7.7	3.6
	3.0	3.0	Corrugation	8	1.8	20	450	60	5.0	4.2
			Sprinkler							
Corn, Sorghum or Beans	3.0	3.0	Furrow-R	17	2.8	30	610	80	3.8	5.0
		3.0	Furrow-C	17	2.8	30	610	65	4.6	4.2
		3.0	Furrow-R	17	2.8	40	610	80	3.8	6.3
		3.0	Furrow-C	17	2.8	40	610	65	4.6	5.3
		2.1	Furrow-R	17	2.8	60	610	80	2.6	6.7
		2.1	Furrow-C	17	2.8	60	610	65	3.2	5.7
		3.0	Contour Furrow (Refer to 30" or 40" furrow with design slope 0.4%)							
			Sprinkler							
Sugar Beets	3.0	3.0	Furrow-R	17	2.1	22	810	80	3.8	4.2
		3.0	Furrow-C	17	2.1	22	810	65	4.6	4.2
			Sprinkler							
Small Grain	3.0	3.0	Border	-	0.0062	50	1210	65	4.6	1.8
		3.0	Furrow-R	17	2.8	30	610	80	3.8	5.0
		3.0	Furrow-C	17	2.8	30	610	65	4.6	4.2
		3.0	Furrow-R	17	2.8	40	610	80	3.8	6.3
		3.0	Furrow-C	17	2.8	40	610	65	4.6	5.3
		3.0	Corrugation	8	1.8	20	450	60	5.0	4.2
			Sprinkler							
Grass	3.0	3.0	Border	-	0.0062	50	1210	65	4.6	1.8
		3.0	Corrugation	8	1.8	20	450	60	5.0	4.2
			Sprinkler							
R = Reuse	C = Cutback									

IRRIGATION DESIGN

U.S. DEPT. OF AGRICULTURE
SOIL CONSERVATION SERVICE

GENERAL SOILS DESCRIPTION: Deep soils with silt loam, loam or very fine sandy loam surface layers and moderately permeable, medium textured subsoils. (Intake Family 1.0)

GROUP NO 7

Sheet 3 of 3

Date 1975

CROPS	NORMAL IRRIGATION DEPTH	NET MOISTURE TO BE REPLACED EACH IRRIGATION	ADAPTED CONSERVATION IRRIGATION METHODS	MAXIMUM SIZE STREAM FOR FURROWS OR CORRUGATIONS	UNIT STREAM BORDERS OR CONTOUR DITCH C.F.S. PER 100 SQ.FT. FURROWS OR CORRUGATIONS G.P.M./100' OF LENGTH	MAXIMUM BORDER WIDTH feet NORMAL FURROW OR CORRUGATION SPACING inches	MAXIMUM LENGTH OF RUN	EST. FIELD EFF	GROSS WATER USED	ESTIMATED TIME REQUIRED
	feet	inches		g.p.m.	c.f.s. or g.p.m.	ft. or in.	feet	%	inches	hours
1	2	3	4	5	6	7	8	9	10	11
SLOPE GROUP 1.1 TO 2.0% (DESIGN SLOPE 1.5%)										
Alfalfa	5.0	5.0	Border	–	0.0052	40	850	60	7.5	3.2
	3.0	3.0	Corrugation	8	1.8	20	450	60	5.0	4.2
			Sprinkler							
Corn, Sorghum or Beans	3.0	3.0	Contour Furrow (Refer to 30" or 40" furrow with design slope 0.4%)							
			Sprinkler							
Sugar Beets	3.0	3.0	Sprinkler							
Small Grain or Grass	3.0	3.0	Border	–	0.0062	40	1210	60	5.0	1.8
		3.0	Corrugation	8	1.8	20	450	60	5.0	4.2
			Sprinkler							
* * * * * * *	* * * *	* * * *	* * * * * *	* * * *	* * * *	* * * *	* * *	* * *	* * *	* * * * *
SLOPE GROUP 2.1 TO 4.0 (DESIGN SLOPE 3.0%)(Contour furrow or sprinkler with terraces)										
Alfalfa	5.0	5.0	Sprinkler							
Corn, Sorghum or Beans	3.0	3.0	Contour Furrow (Refer to 30" or 40" furrow with design slope 0.4%)							
			Sprinkler							
Small Grain or S. Beets	3.0	3.0	Sprinkler							
Grass	3.0	3.0	Border	–	0.0062*	30	860	60	5.0	1.8
		3.0	Corrugation	4	1.8	20	220	60	5.0	4.2
			Sprinkler							
* * * * * * *	* * * *	* * * *	* * * * * *	* * * *	* * * *	* * * *	* * *	* *	* * * *	* * * *
SLOPE GROUP 4.1 TO 8.0% (DESIGN SLOPE 6.0%)(Sprinkler with terraces)										
Alfalfa	5.0	5.0	Sprinkler							
Corn, Sorghum Beans, Grass or Small Grain	3.0	3.0	Sprinkler							

*Corrugations are required to provide adequate spread of border stream.

U.S. DEPT. OF AGRICULTURE
SOIL CONSERVATION SERVICE

IRRIGATION DESIGN

GENERAL SOILS DESCRIPTION Moderately deep soils with silt loam, loam or very fine sandy loam surface layers and moderately permeable clay loam, loam or silt loam subsoils. (Intake Family 1.0)

GROUP NO 8

Sheet 1 of 3
Date 1975

CROPS	NORMAL IRRIGATION DEPTH feet	NET MOISTURE TO BE REPLACED EACH IRRIGATION inches	ADAPTED CONSERVATION IRRIGATION METHODS	MAXIMUM SIZE STREAM FOR FURROWS OR CORRUGATIONS g.p.m	UNIT STREAM BORDERS OR CONTOUR DITCH C.F.S. PER 100 SQ.FT. FURROWS OR CORRUGATIONS G.P.M./100' OF LENGTH c.f.s. or g.p.m	MAXIMUM BORDER WIDTH feet NORMAL FURROW OR CORRUGATION SPACING inches ft. or in.	MAXIMUM LENGTH OF RUN feet	EST. FIELD EFF. %	GROSS WATER USED inches	ESTIMATED TIME REQUIRED hours
1	2	3	4	5	6	7	8	9	10	11
		SLOPE GROUP LESS THAN 0.05% (DESIGN SLOPE LEVEL)								
Alfalfa, Grass	2.5	3.0	Level Border	–	0.016	60	650	80	3.8	0.6
Corn, Sorghum			Sprinkler							
Beans, Sm. Gr										
* * * * *	* * * *	* * * *	* * * * *	* * * *	* * * *	* * * *	* * *	* *	* * * *	* * * *
		SLOPE GROUP 0.05 TO 0.14% (DESIGN SLOPE 0.1%)								
Alfalfa or Grass	2.5	3.0	Border	–	0.0063	60	1200	75	4.0	1.5
			Sprinkler							
Corn, Sorghum or Beans	2.5	3.0	Furrow-R	30	2.8	30	1080	85	3.5	5.0
		3.0	Furrow-C	30	2.8	30	1080	70	4.3	4.2
		3.0	Furrow-R	50	3.6	40	1400	85	3.5	5.2
		3.0	Furrow-C	50	3.6	40	1400	70	4.3	4.4
		2.5	Furrow-R	40	3.4	60	1180	85	2.9	6.7
		2.5	Furrow-C	40	3.4	60	1180	70	3.6	5.7
			Sprinkler							
Sugar Beets	2.5	3.0	Furrow-R	20	2.1	22	950	85	3.5	5.0
		3.0	Furrow-C	20	2.1	22	950	70	4.3	4.2
			Sprinkler							
Small Grain	2.5	3.0	Border	–	0.0063	60	1200	75	4.0	1.5
		3.0	Furrow-R	30	2.8	30	1080	85	3.5	5.0
		3.0	Furrow-C	30	2.8	30	1080	70	4.3	4.2
		3.0	Furrow-R	50	3.6	40	1400	85	3.5	5.2
		3.0	Furrow-C	50	3.6	40	1400	70	4.3	4.4
			Sprinkler							
* * * * *	* * * *	* * * *	* * * * *	* * * *	* * * *	* * * *	* * *	* *	* * * *	* * * *
		SLOPE GROUP 0.15 TO 0.25% (DESIGN SLOPE 0.2%)								
Alfalfa or Grass	2.5	3.0	Border	–	0.0062	60	1210	70	4.3	1.6
			Sprinkler							
Corn, Sorghum or Beans	2.5	3.0	Furrow-R	30	2.8	30	1080	85	3.5	5.0
		3.0	Furrow-C	30	2.8	30	1080	70	4.3	4.2
		3.0	Furrow-R	50	3.5	40	1430	85	3.5	5.3
		3.0	Furrow-C	50	3.5	40	1430	70	4.3	4.5
		2.5	Furrow-R	40	3.4	60	1180	85	2.9	6.7
		2.5	Furrow-C	40	3.4	60	1180	70	3.6	5.7
			Sprinkler							
Sugar Beets	2.5	3.0	Furrow-R	20	2.1	22	950	85	3.5	5.0
		3.0	Furrow-C	20	2.1	22	950	70	4.3	4.2
			Sprinkler							
Small Grain	2.5	3.0	Border	–	0.0062	60	1210	70	4.3	1.6
		3.0	Furrow-R	30	2.8	30	1080	85	3.5	5.0
		3.0	Furrow-C	30	2.8	30	1080	70	4.3	4.2
		3.0	Furrow-R	50	3.5	40	1430	85	3.5	5.3
		3.0	Furrow-C	50	3.5	40	1430	70	4.3	4.5
			Sprinkler							
R = Reuse	C = Cutback									

IRRIGATION DESIGN

U.S. DEPT. OF AGRICULTURE
SOIL CONSERVATION SERVICE

GENERAL SOILS DESCRIPTION: Moderately deep soils with silt loam, loam or very fine sandy loam surface layers and moderately permeable clay loam, loam or silt loam subsoils. (Intake Family 1.0)

GROUP NO 8

 Date 1975

CROPS	NORMAL IRRIGATION DEPTH	NET MOISTURE TO BE REPLACED EACH IRRIGATION	ADAPTED CONSERVATION IRRIGATION METHODS	MAXIMUM SIZE STREAM FOR FURROWS OR CORRUGATIONS	UNIT STREAM BORDERS OR CONTOUR DITCH C.F.S. PER 100 SQ.FT. FURROWS OR CORRUGATIONS G.P.M./100' OF LENGTH	MAXIMUM BORDER WIDTH feet NORMAL FURROW OR CORRUGATION SPACING inches	MAXIMUM LENGTH OF RUN	EST. FIELD EFF.	GROSS WATER USED	ESTIMATED TIME REQUIRED
	feet	inches		g.p.m.	c.f.s. or g.p.m.	ft. or in.	feet	%	inches	hours
1	2	3	4	5	6	7	8	9	10	11
		SLOPE GROUP 0.26 TO 0.55% (DESIGN SLOPE 0.4%)								
Alfalfa or Grass	2.5	3.0	Border	-	0.0062	60	1200	65	4.6	1.8
			Sprinkler							
Corn, Sorghum or Beans	2.5	3.0	Furrow-R	30	2.8	30	1080	85	3.5	5.0
		3.0	Furrow-C	30	2.8	30	1080	70	4.3	4.2
		3.0	Furrow-R	30	3.2	40	940	85	3.5	5.8
		3.0	Furrow-C	30	3.2	40	940	70	4.3	4.9
		2.3	Furrow-R	30	3.2	60	940	85	2.7	6.7
		2.3	Furrow-C	30	3.2	60	940	70	3.3	5.7
			Sprinkler							
Sugar Beets	2.5	3.0	Furrow-R	20	2.1	22	950	85	3.5	5.0
		3.0	Furrow-C	20	2.1	22	950	70	4.3	4.2
			Sprinkler							
Small Grain	2.5	3.0	Border	-	0.0062	60	1200	65	4.6	1.8
		3.0	Furrow-R	30	2.8	30	1080	85	3.5	5.0
		3.0	Furrow-C	30	2.8	30	1080	70	4.3	4.2
		3.0	Furrow-R	30	3.2	40	940	85	3.5	5.8
		3.0	Furrow-C	30	3.2	40	940	70	4.3	4.9
			Sprinkler							
* * * * * * *	* * * *	* * * *	* * * * * *	* * * *	* * * *	* * * *	* * *	* *	* * * *	* * * *
		SLOPE GROUP 0.56 TO 1.0% (DESIGN SLOPE 0.7%)								
Alfalfa or Grass	2.5	3.0	Border	-	0.0062	50	1200	65	4.6	1.8
		3.0	Corrugation	8	1.8	20	450	60	5.0	4.2
			Sprinkler							
Corn, Sorghum or Beans	2.5	3.0	Furrow-R	17	2.8	30	610	80	3.8	5.0
		3.0	Furrow-C	17	2.8	30	610	65	4.6	4.2
		3.0	Furrow-R	17	2.8	40	610	80	3.8	6.3
		3.0	Furrow-C	17	2.8	40	610	65	4.6	5.3
		2.1	Furrow-R	17	2.8	60	610	80	2.6	6.7
		2.1	Furrow-C	17	2.8	60	610	65	3.2	5.7
			Sprinkler							
Sugar Beets	2.5	3.0	Furrow-R	17	2.1	22	810	80	3.8	5.0
		3.0	Furrow-C	17	2.1	22	810	65	4.6	4.2
			Sprinkler							
Small Grain	2.5	3.0	Border	-	0.0062	50	1200	65	4.6	1.8
		3.0	Furrow-R	17	2.8	30	610	80	3.8	5.0
		3.0	Furrow-C	17	2.8	30	610	65	4.6	4.2
		3.0	Furrow-R	17	2.8	40	610	80	3.8	6.3
		3.0	Furrow-C	17	2.8	40	610	65	4.6	5.6
		3.0	Corrugation	8	1.8	20	450	60	5.0	4.2
			Sprinkler							
R = Reuse	C = Cutback									

U.S. DEPT. OF AGRICULTURE
SOIL CONSERVATION SERVICE

IRRIGATION DESIGN

GENERAL SOILS DESCRIPTION: Moderately deep soils with silt loam, loam or very fine sandy loam surface layers and moderately permeable clay loam, loam or silt loam subsoils. (Intake Family 1.0)

GROUP NO 8

Sheet 3 of 3
Date 1975

CROPS	NORMAL IRRIGATION DEPTH feet	NET MOISTURE TO BE REPLACED EACH IRRIGATION inches	ADAPTED CONSERVATION IRRIGATION METHODS	MAXIMUM SIZE STREAM FOR FURROWS OR CORRUGATIONS g.p.m	UNIT STREAM BORDERS OR CONTOUR DITCH C.F.S. PER 100 SQ.FT. FURROWS OR CORRUGATIONS G.P.M./100' OF LENGTH c.f.s. or g.p.m.	MAXIMUM BORDER WIDTH feet NORMAL FURROW OR CORRUGATION SPACING inches ft. or in	MAXIMUM LENGTH OF RUN feet	EST. FIELD EFF %	GROSS WATER USED inches	ESTIMATED TIME REQUIRED hours
1	2	3	4	5	6	7	8	9	10	11
SLOPE GROUP 1.1 TO 2.0% (DESIGN SLOPE 1.5%)										
Alfalfa, Grass or Small Grain	2.5	3.0	Border*	-	0.0062	40	800	60	5.0	1.8
		3.0	Corrugation	8	1.8	20	450	60	5.0	4.2
			Sprinkler							
Corn, Sorghum or Beans	2.5	3.0	Contour Furrow (Refer to 30" or 40" furrow with design slope 0.4%)							
			Sprinkler							
Sugar Beets	2.5	3.0	Sprinkler							
SLOPE GROUP 2.1 TO 4.0% (DESIGN SLOPE 3.0%) (Contour furrow or sprinkler with terraces)										
Alfalfa, Beets or Small Grain	2.5	3.0	Sprinkler							
Corn, Sorghum or Beans	2.5	3.0	Contour Furrow (Refer to 30" or 40" furrow with design slope 0.4%)							
			Sprinkler							
Grass	2.5	3.0	Border*	-	0.0062	30	800	60	5.0	1.8
		3.0	Corrugation	4	1.8	20	220	60	5.0	4.2
			Sprinkler							
SLOPE GROUP 4.1 TO 8.0% (DESIGN SLOPE 6.0%) (Sprinkler with terraces)										
Alfalfa, Grass Corn, Sorghum Beans or Small Grain	2.5	3.0	Sprinkler							

* Corrugations are required to provide adequate spread of border stream

USDA SCS LINCOLN NEBR 1971

Rev. 5-71 5,0-28,722

IG Notice KA-3, 10-14-77

IRRIGATION DESIGN

GENERAL SOILS DESCRIPTION: Deep soils with fine sandy loam and loam surface layers and subsoils that have moderately rapid permeability. (Intake Family 1.5)

GROUP NO 9

Sheet 1 of 3
Date 1975

CROPS	NORMAL IRRIGATION DEPTH	NET MOISTURE TO BE REPLACED EACH IRRIGATION	ADAPTED CONSERVATION IRRIGATION METHODS	MAXIMUM SIZE STREAM FOR FURROWS OR CORRUGATIONS	UNIT STREAM BORDERS OR CONTOUR DITCH C.F.S. PER 100 SQ.FT. FURROWS OR CORRUGATIONS G.P.M./100' OF LENGTH	MAXIMUM BORDER WIDTH feet NORMAL FURROW OR CORRUGATION SPACING inches	MAXIMUM LENGTH OF RUN	EST. FIELD EFF.	GROSS WATER USED	ESTIMATED TIME REQUIRED
	feet	inches		g.p.m.	c.f.s. or g.p.m.	ft. or in.	feet	%	inches	hours
1	2	3	4	5	6	7	8	9	10	11
		SLOPE GROUP LESS THAN 0.05% (DESIGN SLOPE LEVEL)								
Alfalfa	5.0	4.5	Level Border	-	0.0145	60	620	80	5.6	0.7
			Sprinkler							
Corn, Sorghum Beans, Grass or Small Grain	3.0	3.0	Level Border	-	0.023	60	500	80	3.8	0.4
			Sprinkler							
* * * * * * *	* * * *	* * * *	* * * * * *	* * * *	* * * *	* * * *	* * *	* *	* * * *	* * * *
		SLOPE GROUP 0.05 TO 0.14% (DESIGN SLOPE 0.1%)								
Alfalfa	5.0	4.5	Border	-	0.0075	60	1000	80	5.6	1.8
			Sprinkler							
Corn, Sorghum or Beans	3.0	3.0	Furrow-R	30	3.7	30	810	85	3.5	3.6
		3.0	Furrow-R	50	4.6	40	1090	85	3.5	3.9
		2.4	Furrow-R	40	4.4	60	910	85	2.8	5.0
			Sprinkler							
Sugar Beets	3.0	3.0	Furrow-R	20	2.7	22	740	85	3.5	3.6
			Sprinkler							
Small Grain	3.0	3.0	Border	-	0.0095	60	790	75	4.0	1.0
		3.0	Furrow-R	30	3.7	30	810	85	3.5	3.6
		3.0	Furrow-R	50	4.6	40	1090	85	3.5	3.9
			Sprinkler							
Grass	3.0	3.0	Border	-	0.0095	60	790	75	4.0	1.0
			Sprinkler							
* * * * * * *	* * * *	* * * *	* * * * * *	* * * * *	* * * *	* * * *	* * *	* *	* * * *	* * * *
		SLOPE GROUP 0.15 TO 0.25% (DESIGN SLOPE 0.2%)								
Alfalfa	5.0	4.5	Border	-	0.0074	60	1020	75	5.3	1.9
			Sprinkler							
Corn, Sorghum or Beans	3.0	3.0	Furrow-R	30	3.7	30	810	85	3.5	3.6
		3.0	Furrow-R	50	4.5	40	1120	85	3.5	4.0
		2.3	Furrow-R	40	4.3	60	930	85	2.7	5.0
			Sprinkler							
Sugar Beets	3.0	3.0	Furrow-R	20	2.7	22	740	85	3.5	3.6
			Sprinkler							
Small Grain	3.0	3.0	Border	-	0.0094	60	800	70	4.3	1.1
		3.0	Furrow-R	30	3.7	30	810	85	3.5	3.6
		3.0	Furrow-R	50	4.5	40	1120	85	3.5	4.0
			Sprinkler							
Grass	3.0	3.0	Border	-	0.0094	60	800	70	4.3	1.1
			Sprinkler							

IG Notice KA-3, 10-14-77

IRRIGATION DESIGN

U.S. DEPT. OF AGRICULTURE
SOIL CONSERVATION SERVICE

GENERAL SOILS DESCRIPTION. Deep soils with fine sandy loam and loam surface layers and subsoils that have moderately rapid permeability.

GROUP NO. 9

(Intake Family 1.5)

Sheet 2 of 3
Date 1975

CROPS	NORMAL IRRIGATION DEPTH	NET MOISTURE TO BE REPLACED EACH IRRIGATION	ADAPTED CONSERVATION IRRIGATION METHODS	MAXIMUM SIZE STREAM FOR FURROWS OR CORRUGATIONS	UNIT STREAM BORDERS OR CONTOUR DITCH C.F.S. PER 100 SQ FT. FURROWS OR CORRUGATIONS G.P.M./100' OF LENGTH	MAXIMUM BORDER WIDTH feet NORMAL FURROW OR CORRUGATION SPACING inches	MAXIMUM LENGTH OF RUN	EST. FIELD EFF.	GROSS WATER USED	ESTIMATED TIME REQUIRED
	feet	inches		g.p.m	c.f.s. or g.p.m.	ft or in.	feet	%	inches	hours
1	2	3	4	5	6	7	8	9	10	11
			SLOPE GROUP 0.26 TO 0.55% (DESIGN SLOPE 0.4%)							
Alfalfa	5.0	4.5	Border	–	0.0074	60	1020	70	6.4	2.0
			Sprinkler							
Corn, Sorghum or Beans	3.0	3.0	Furrow-R	30	3.7	30	810	85	3.5	3.6
		3.0	Furrow-R	30	4.1	40	740	85	3.5	4.3
		2.2	Furrow-R	30	4.1	60	770	85	2.5	5.0
			Sprinkler							
Sugar Beets	3.0	3.0	Furrow-R	20	2.7	22	740	85	3.5	3.6
			Sprinkler							
Small Grain	3.0	3.0	Border	–	0.0093	60	810	65	4.6	1.2
		3.0	Furrow-R	30	3.7	30	810	85	3.5	3.6
		3.0	Furrow-R	30	4.1	40	740	85	3.5	4.3
			Sprinkler							
Grass	3.0	3.0	Border	–	0.0093	60	810	65	4.6	1.2
			Sprinkler							
* * * * * * *	* * * *	* * * *	* * * * * * * * * * * *	* * * *	* * * * *	* * * *	* * *	* *	* * * *	* * * *
			SLOPE GROUP 0.56 TO 1.0% (DESIGN SLOPE 0.7%)							
Alfalfa	5.0	4.5	Border	–	0.0074	50	1020	70	6.4	2.1
			Sprinkler							
Corn, Sorghum or Beans	3.0	3.0	Furrow-R	17	3.6	30	480	80	3.8	3.8
		3.0	Furrow-R	17	3.6	40	480	80	3.8	4.7
		2.0	Furrow-R	17	3.7	60	460	80	2.5	5.0
		3.0	Contour Furrow (Refer to 30" or 40" furrow with design slope 0.4%)							
			Sprinkler							
Sugar Beets	3.0	3.0	Furrow-R	17	2.7	22	630	80	3.8	3.1
			Sprinkler							
Small Grain	3.0	3.0	Border	–	0.0093	50	810	65	4.6	1.2
		3.0	Furrow-R	17	3.6	30	480	80	3.8	3.8
		3.0	Furrow-R	17	3.6	40	480	80	3.8	4.7
			Sprinkler							
Grass	3.0	3.0	Border	–	0.0093	50	810	65	4.6	1.2
			Sprinkler							

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IRRIGATION DESIGN

U.S. DEPT. OF AGRICULTURE
SOIL CONSERVATION SERVICE

GENERAL SOILS DESCRIPTION: Deep soils with fine sandy loam and loam surface layers and subsoils that have moderately rapid permeability. (Intake Family 1.5)

GROUP NO 9

Sheet 3 of 3
Date 1975

CROPS	NORMAL IRRIGATION DEPTH feet	NET MOISTURE TO BE REPLACED EACH IRRIGATION inches	ADAPTED CONSERVATION IRRIGATION METHODS	MAXIMUM SIZE STREAM FOR FURROWS OR CORRUGATIONS g.p.m	UNIT STREAM BORDERS OR CONTOUR DITCH C.F.S. PER 100 SQ.FT. FURROWS OR CORRUGATIONS G.P.M./100' OF LENGTH c.f.s. or g.p.m	MAXIMUM BORDER WIDTH feet NORMAL FURROW OR CORRUGATION SPACING inches ft. or in.	MAXIMUM LENGTH OF RUN feet	EST. FIELD EFF. %	GROSS WATER USED inches	ESTIMATED TIME REQUIRED hours
1	2	3	4	5	6	7	8	9	10	11
SLOPE GROUP 1.1 TO 2.0% (DESIGN SLOPE 1.5%)										
Alfalfa	5.0	4.5	Border Sprinkler	-	0.0074	40	600	65	6.9	2.2
Corn, Sorghum or Beans	3.0	3.0	Contour Furrow (Refer to 30" or 40" furrow with design slope 0.4%) Sprinkler							
Sugar Beets	3.0	3.0	Sprinkler							
Small Grain or Grass	3.0	3.0	Border Sprinkler	-	0.0093	40	480	60	5.0	1.2
* * * * * * *	* * * *	* * * *	* * * * * *	* * * *	* * * * *	* * * *	* * *	* *	* * * *	* * * * *
SLOPE GROUP 2.1 TO 4.0% (DESIGN SLOPE 3.0%)										
Alfalfa	5.0	4.5	Sprinkler							
Corn, Sorghum Beans, Beets or Small Grain	3.0	3.0	Sprinkler							
Grass	3.0	3.0	Border Sprinkler	-	0.0093	30	570	60	5.0	1.2
* * * * * * *	* * * * *	* * * *	* * * * * *	* * * *	* * * * *	* * * *	* * *	* *	* * * *	* * * * *
SLOPE GROUP 4.1 TO 8.0% (DESIGN SLOPE 6.0%)										
Alfalfa	5.0	4.5	Sprinkler							
Corn, Sorghum Beans, Grass or Small Grain	3.0	3.0	Sprinkler							

U.S. DEPT. OF AGRICULTURE
SOIL CONSERVATION SERVICE

IRRIGATION DESIGN

GENERAL SOILS DESCRIPTION: Soils are moderately deep over sand with sandy loam to loam surface layers and moderately rapid to rapidly permeable subsoils.

GROUP NO 10

(Intake Family 1.5)

Sheet 1 of 2
Date 1975

CROPS	NORMAL IRRIGATION DEPTH	NET MOISTURE TO BE REPLACED EACH IRRIGATION	ADAPTED CONSERVATION IRRIGATION METHODS	MAXIMUM SIZE STREAM FOR FURROWS OR CORRUGATIONS	UNIT STREAM BORDERS OR CONTOUR DITCH C.F.S. PER 100 SQ.FT. FURROWS OR CORRUGATIONS G.P.M./100' OF LENGTH	MAXIMUM BORDER WIDTH feet NORMAL FURROW OR CORRUGATION SPACING inches	MAXIMUM LENGTH OF RUN	EST. FIELD EFF.	GROSS WATER USED	ESTIMATED TIME REQUIRED
	feet	inches		g.p.m	c.f.s. or g.p.m.	ft. or in.	feet	%	inches	hours
1	2	3	4	5	6	7	8	9	10	11
		SLOPE GROUP LESS THAN 0.05% (DESIGN SLOPE LEVEL)								
Alfalfa	5.0	3.0	Level Border	-	0.023	60	500	80	3.8	0.38
			Sprinkler							
Corn, Sorghum Beans, Grass or Small Grain	3.0	2.0	Level Border	-	0.045	60	400	80	2.5	0.13
			Sprinkler							
* * * * * * *	* * * *	* * * *	* * * * * *	* * * *	* * * *	* * * *	* * *	* *	* * * *	* * * *
		SLOPE GROUP 0.05 TO 0.14% (DESIGN SLOPE 0.1%)								
Alfalfa	5.0	3.0	Border	-	0.0095	60	790	75	4.0	1.0
			Sprinkler							
Corn, Sorghum or Beans	3.0	2.0	Furrow-R	30	4.1	30	740	80	2.5	2.2
		2.0	Furrow-R	50	4.5	40	1120	80	2.5	2.6
			Sprinkler							
Sugar Beets	3.0	2.0	Furrow-R	20	2.9	22	690	80	2.5	2.3
			Sprinkler							
Small Grain	3.0	2.0	Border	-	0.0121	60	620	70	2.9	0.6
		2.0	Furrow-R	30	4.1	30	740	80	2.5	2.2
		2.0	Furrow-R	50	4.5	40	1120	80	2.5	2.6
			Sprinkler							
Grass	3.0	2.0	Border	-	0.0121	60	620	70	2.9	0.6
			Sprinkler							
* * * * * * *	* * * *	* * * *	* * * * * *	* * * *	* * * *	* * * *	* * *	* *	* * * *	* * * * *
		SLOPE GROUP 0.15 TO 0.25% (DESIGN SLOPE 0.2%)								
Alfalfa	5.0	3.0	Border	-	0.0094	60	800	70	4.3	1.1
			Sprinkler							
Corn, Sorghum or Beans	3.0	2.0	Furrow-R	30	4.1	30	740	80	2.5	2.2
		2.0	Furrow-R	50	4.4	40	1140	80	2.5	2.7
			Sprinkler							
Sugar Beets	3.0	2.0	Furrow-R	20	2.9	22	690	80	2.5	2.3
			Sprinkler							
Small Grain	3.0	2.0	Border	-	0.012	60	620	65	3.1	0.6
		2.0	Furrow-R	30	4.1	30	740	80	2.5	2.2
		2.0	Furrow-R	50	4.4	40	1140	80	2.5	2.7
			Sprinkler							
Grass	3.0	2.0	Border	-	0.012	60	620	65	3.1	0.6
			Sprinkler							
* * * * * * *	* * * *	* * * *	* * * * * *	* * * *	* * * *	* * * *	* * *	* *	* * * *	* * * * *
		SLOPE GROUP 0.26 TO 0.55% (DESIGN SLOPE 0.4%)								
Alfalfa	5.0	3.0	Border	-	0.0093	60	810	65	4.6	1.2
			Sprinkler							
Corn, Sorghum or Beans	3.0	2.0	Furrow-R	30	4.0	30	750	80	2.5	2.3
		2.0	Furrow-R	30	4.0	40	750	80	2.5	2.9
			Sprinkler							
Sugar Beets	3.0	2.0	Furrow-R	20	2.9	22	690	80	2.5	2.3
			Sprinkler							
Small Grain	3.0	2.0	Border	-	0.0119	60	630	60	3.3	0.7
		2.0	Furrow-R	30	4.0	30	750	80	2.5	2.3
		2.0	Furrow-R	30	4.0	40	750	80	2.5	2.9
			Sprinkler							
Grass	3.0	2.0	Border	-	0.0119	60	630	60	3.3	0.7
			Sprinkler							

IRRIGATION DESIGN

U.S. DEPT. OF AGRICULTURE
SOIL CONSERVATION SERVICE

GENERAL SOILS DESCRIPTION. Soils are moderately deep over sand with sandy loam to loam surface layers and moderately rapid to rapidly permeable subsoils. (Intake Family 1.5)

GROUP NO 10

Sheet 2 of 2
Date 1975

CROPS	NORMAL IRRIGATION DEPTH	NET MOISTURE TO BE REPLACED EACH IRRIGATION	ADAPTED CONSERVATION IRRIGATION METHODS	MAXIMUM SIZE STREAM FOR FURROWS OR CORRUGATIONS	UNIT STREAM BORDERS OR CONTOUR DITCH C.F.S. PER 100 SQ.FT. FURROWS OR CORRUGATIONS G.P.M./100' OF LENGTH	MAXIMUM BORDER WIDTH feet NORMAL FURROW OR CORRUGATION SPACING inches	MAXIMUM LENGTH OF RUN	EST. FIELD EFF.	GROSS WATER USED	ESTIMATED TIME REQUIRED
	feet	inches		g.p.m.	c.f.s. or g.p.m.	ft. or in.	feet	%	inches	hours
1	2	3	4	5	6	7	8	9	10	11
			SLOPE GROUP 0.56 TO 1.0% (DESIGN SLOPE 0.7%)							
Alfalfa	5.0	3.0	Border	-	0.0093	50	810	65	4.6	1.2
			Sprinkler							
Corn, Sorghum	3.0	2.0	Furrow-R	17	3.4	30	500	80	2.5	2.6
or Beans		1.9	Furrow-R	17	3.5	36"	490	80	2.5	2.9
		2.0	Contour Furrow (Refer to 30" or 40" furrow with design slope 0.4%)							
			Sprinkler							
Sugar Beets	3.0	2.0	Furrow-R	17	3.0	22	570	75	2.7	2.2
			Sprinkler							
Small Grain	3.0	2.0	Border	-	0.0117	50	640	60	3.3	0.7
		2.0	Furrow-R	17	3.4	30	500	80	2.5	2.6
		1.9	Furrow-R	17	3.5	36*	490	80	2.5	2.9
			Sprinkler							
Grass	3.0	2.0	Border	-	0.0117	50	640	60	3.3	0.7
			Sprinkler							
* * * * * * *	* * * *	* * * *	* * * * * *	* * * * *	* * * * *	* * * * *	* * *	* * *	* * * *	* * * * *
			SLOPE GROUP 1.1 TO 2.0% (DESIGN SLOPE 1.5%)							
Alfalfa	5.0	3.0	Border	-	0.0093	40	420	60	5.0	1.2
			Sprinkler							
Corn, Sorghum	3.0	2.0	Contour Furrow (Refer to 30" or 40" furrow with design slope 0.4%)							
or Beans			Sprinkler							
Sugar Beets	3.0	2.0	Sprinkler							
Small Grain	3.0	2.0	Border	-	0.0117	40	380	55	3.6	0.7
			Sprinkler							
Grass	3.0	2.0	Border	-	0.0117	40	640	55	3.6	0.7
			Sprinkler							
* * * * * * *	* * * *	* * * *	* * * * * *	* * * * *	* * * * *	* * * * *	* * *	* * *	* * * *	* * * *
			SLOPE GROUP 2.1 TO 4.0% (DESIGN SLOPE 3.0%)							
Alfalfa	5.0	3.0	Sprinkler							
Corn, Sorghum	3.0	2.0	Sprinkler							
Beans, Beets										
or Small Grain										
Grass	3.0	2.0	Border	-	0.0117	30	450	55	3.6	0.7
			Sprinkler							
* * * * * * *	* * * *	* * * *	* * * * * *	* * * * *	* * * * *	* * * * *	* * *	* * *	* * * *	* * * *
			SLOPE GROUP 4.1 TO 8.0% (DESIGN SLOPE 6.0%)							
Alfalfa	5.0	3.0	Sprinkler							
Corn, Sorghum	3.0	2.0	Sprinkler							
Beans, Grass										
or Small Grain										

* 36" furrow spacing recommended instead of 40" to obtain sufficient lateral spread

IRRIGATION DESIGN

GENERAL SOILS DESCRIPTION: Deep soils with loamy fine sand or loamy sand surface layers and moderately rapid to rapidly permeable subsoils. (Intake Family 2.0)

GROUP NO 11

Sheet 1 of 1

Date 1975

U.S. DEPT. OF AGRICULTURE
SOIL CONSERVATION SERVICE

CROPS	NORMAL IRRIGATION DEPTH	NET MOISTURE TO BE REPLACED EACH IRRIGATION	ADAPTED CONSERVATION IRRIGATION METHODS	MAXIMUM SIZE STREAM FOR FURROWS OR CORRUGATIONS	UNIT STREAM BORDERS OR CONTOUR DITCH C.F.S. PER 100 SQ.FT. FURROWS OR CORRUGATIONS G.P.M./100' OF LENGTH	MAXIMUM BORDER WIDTH feet NORMAL FURROW OR CORRUGATION SPACING inches	MAXIMUM LENGTH OF RUN	EST. FIELD EFF.	GROSS WATER USED	ESTIMATED TIME REQUIRED
	feet	inches		g.p.m.	c.f.s. or g.p.m.	ft. or in.	feet	%	inches	hours
1	2	3	4	5	6	7	8	9	10	11
		SLOPE	GROUP LESS THAN 0.05%	(DESIGN SLOPE LEVEL)						
Alfalfa	5.0	3.0	Sprinkler							
Corn, Sorghum	3.0	2.0	Sprinkler							
Small Grain										
or Grass										
* * * * * *	* * * *	* * *	* * * * * *	* * * *	* * * *	* * * *	* * *	* *	* * * *	* * * *
		SLOPE	GROUP 0.05 TO 0.14%	(DESIGN SLOPE 0.1%)						
Alfalfa	5.0	3.0	Sprinkler							
Corn, Sorghum	3.0	2.0	Furrow-R	30	5.4	30	560	70	2.9	1.8
or Small Grain		2.0	Furrow-R	50	5.7	40	880	70	2.9	2.2
			Sprinkler							
Grass	3.0	2.0	Sprinkler							
* * * * * *	* * * *	* * *	* * * * * *	* * * *	* * * *	* * * *	* * *	* *	* * * *	* * * *
		SLOPE	GROUP 0.15 TO 0.25%	(DESIGN SLOPE 0.2%)						
Alfalfa	5.0	3.0	Sprinkler							
Corn, Sorghum	3.0	2.0	Furrow-R	30	5.2	30	580	65	3.1	1.9
or Small Grain		2.0	Furrow-R	50	5.6	40	890	65	3.1	2.2
			Sprinkler							
Grass	3.0	2.0	Sprinkler							
* * * * * *	* * * *	* * *	* * * * * *	* * * *	* * * *	* * * *	* * *	* *	* * * *	* * * *
		SLOPE	GROUP 0.26 TO 0.55%	(DESIGN SLOPE 0.4%)						
Alfalfa	5.0	3.0	Sprinkler							
Corn, Sorghum	3.0	2.0	Furrow-R	30	5.0	30	600	65	3.1	1.9
or Small Grain		2.0	Furrow-R	30	5.0	36*	600	65	3.1	2.2
			Sprinkler							
Grass	3.0	2.0	Sprinkler							
* * * * * *	* * * *	* * *	* * * * * *	* * * *	* * * *	* * * *	* * *	* *	* * * *	* * * *
		SLOPE	GROUP 0.56 TO 1.0%	(DESIGN SLOPE 0.7%)						
Alfalfa	5.0	3.0	Sprinkler							
Corn, Sorghum	3.0	2.0	Furrow-R	17	4.3	30	400	60	3.3	2.2
or Small Grain		1.9	Furrow-R	17	4.4	36*	390	60	3.2	2.3
			Sprinkler							
Grass	3.0	2.0	Sprinkler							
* * * * * *	* * * *	* * *	* * * * * *	* * * *	* * * *	* * * *	* * *	* *	* * * *	* * * *
	SLOPE GROUP	1.1 TO 8.0%	(DESIGN SLOPES 1.5%,	3.0% AND 6.0%)						
Alfalfa	5.0	3.0	Sprinkler							
Corn, Sorghum	3.0	2.0	Sprinkler							
Small Grain										
or Grass										

* Maximum furrow space is 36" to allow adequate spread

IRRIGATION DESIGN

U.S. DEPT. OF AGRICULTURE
SOIL CONSERVATION SERVICE

GENERAL SOILS DESCRIPTION: Deep rapidly permeable soils with sand or fine sand textures throughout.

GROUP NO 12

(Intake Family 3.0)

Sheet 1 of 1
Date 1975

CROPS	NORMAL IRRIGATION DEPTH feet	NET MOISTURE TO BE REPLACED EACH IRRIGATION inches	ADAPTED CONSERVATION IRRIGATION METHODS	MAXIMUM SIZE STREAM FOR FURROWS OR CORRUGATIONS g.p.m.	UNIT STREAM BORDERS OR CONTOUR DITCH C.F.S. PER 100 SQ.FT. FURROWS OR CORRUGATIONS G.P.M./100' OF LENGTH c.f.s. or g.p.m	MAXIMUM BORDER WIDTH feet NORMAL FURROW OR CORRUGATION SPACING inches ft. or in.	MAXIMUM LENGTH OF RUN feet	EST. FIELD EFF. %	GROSS WATER USED inches	ESTIMATED TIME REQUIRED hours
1	2	3	4	5	6	7	8	9	10	11
SLOPE GROUPS LEVEL TO 8.0% (DESIGN SLOPES: LEVEL, 0.1, 0.2, 0.4, 0.7, 1.5, 3.0 AND 6.0%)										
Corn, Sorghum Small Grain or Grass	3.0	1.5	Sprinkler							

PART 5 - SPRINKLER IRRIGATION

A. General Information

In sprinkler irrigation, water is applied as a stream or spray formed from the flow of water under pressure through small orifices or nozzles. This spray is moved through the air and allowed to fall on the land surface in a relatively uniform pattern at a rate approximately equal to or less than the intake rate the soil. This method of water application is similar to rainfall. Other ver low pressure sprinkler systems have been developed which produce application r higher than the intake rate of the soil. These systems require a special desi

Equipment and techniques for the application of water by the sprinkler method so varied that it is impractical to give all the specific data for this method irrigation in an irrigation guide.

The following discussion is aimed at giving guidelines for the selection of the type of system best suited for the irrigator and location and the design requirements that the selected system should meet. Design information is presented for the most common sprinkler systems used in Kansas. For more detai information on the design of these and other sprinkler systems, see the SCS National Engineering Handbook Section 15, Chapter 11 - Sprinkle Irrigation.

Sprinkler irrigation systems can vary substantially in delivery efficiency. Losses are due to evaporation of the spray, evaporation from soil surfaces, moisture intercepted on the leaves during irrigation and non-uniform distributi High winds can distort the irrigation pattern severely. If application rate exceeds soil intake rate, then surface runoff seriously decreases efficiency. Table 5.1 gives a range of probable system efficiencies (E_q) of the low quarter for well planned sprinkler systems.

TABLE 5.1

System Efficienices for Sprinkler Systems

Type of Sprinkler	Range of Eq
Periodic Move	60 to 75%
Fixed Gun	50 to 60%
Solid Set	60 to 85%
Traveling Gun	55 to 70%
Center Pivot	75 to 85%
Linear Move	80 to 90%

Page 11-24 and 11-25, NEH-15, Chapter 11, Sprinkle Irrigation

Eq = DU x AE

DU = Distribution Uniformity

DU = Average low quarter / Average depth x 100

AE = Effective portion of applied water

AE = Average depth / Gross applied x 100

Intake rates under sprinkler irrigation do not conform to those for flood or furrow. Table 5.2, page 5-3, has been prepared as a guide for maximum application rate. Fields irrigated by the sprinkler method often have varied and undulating slopes. The slope used in selecting the slope group in Table 5.2 is the one found by using the weighted average slope method. A sprinkler system that will apply water at a rate equal to or less than the rate shown in the table will be satisfactory to use in applying water. A center pivot or other continuous move type sprinkler system is different from a stationary system in that its application rate is not a constant, but rather it is changeable. At a given point in the field the rate starts at zero, raises to a peak and then drops off again to zero as the sprinkler system passes that point.

Table 5.2 Example:

Determine the maximum sprinkler application rates for the following conditions.

Sorghum on Harney silt loam (0.3 intake family). Net application is 2.0 inches. Design slope is estimated to be 1-3 percent. Usual residue is estimated at 1500 pounds/acre. From Table 5.2, the application rate for the above parameters and 2000 pounds of residue equals 0.6 inch/hour. For 1500 pounds of residue 0.6 x .95 = 0.57 inch/hour maximum allowable application rate.

Same situation with net application reduced to 1.00 inch. From Table 5.2, application rate for 2000 pounds of residue equals 1.5 inches/hour. For 1500 pounds, 1.5 x .95 = 1.43 inches/hour maximum allowable application rate.

Sprinkler systems have some capability of modifying the temperature in the plant environment both in frost protection and reducing high temperatures. Also, sprinkler systems can be used to apply fertilizers, soil amendments and pesticides. These applications are known as chemigation.

B. <u>Types of Sprinklers</u>

Sprinklers spray the water onto the land through nozzles in the sprinkler heads. These are classified according to the pressure required for proper distribution of the water applied and whether they are fixed or revolving (impact).

1. <u>Low Pressure - Revolving Sprinklers</u> - These sprinklers operate at 5 to 15 pounds per square inch (psi) with a wetted diameter of 20 to 50 feet and recommended minimum application rate of 0.40 inch/hour. These sprinklers are adapted to small acreages and where gravity pressure can be utilized but confined to soils with intake rates at or exceeding 0.50 inch/hour.

TABLE 5.2

<u>MAXIMUM SPRINKLER APPLICATION RATE (Inches/Hour)</u>

For 2000# Actual Residue at Planting

Irrig. Design Group	Design Slope Group	Net Irrigation Application (Inches)											
		0.5	0.75	1.0	1.25	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
1 & 2 (0.1)	0 – 1	4.8	3.0	1.0	0.6	0.4	0.3						
	1.1 – 3	4.8	0.8	0.5	0.4	0.3	0.2						
3 & 4 (0.3)	0 – 1	4.8	4.8	3.0	1.8	1.4	0.9	0.6	0.5	0.4	0.3	0.3	0.2
	1.1 – 3	4.8	2.4	1.5	1.2	1.0	0.6	0.5	0.4	0.3	0.2	0.2	0.2
	3.1 – 5	1.9	1.1	0.9	0.7	0.6	0.5	0.4	0.3	0.3	0.2	0.2	0.2
	> 5	1.2	0.8	0.6	0.6	0.5	0.4	0.3	0.2	0.2	0.2	0.2	0.2
5 & 6 (0.5)	0 – 1	4.8	4.8	4.2	3.0	2.2	1.5	1.1	1.0	0.9	0.8	0.6	0.4
	1.1 – 3	4.8	3.6	2.5	2.0	1.6	1.1	1.0	0.9	0.8	0.7	0.6	0.4
	3.1 – 5	2.8	1.9	1.5	1.2	1.1	1.0	0.8	0.7	0.6	0.5	0.4	0.4
	> 5	1.8	1.4	1.1	1.0	1.0	0.8	0.7	0.6	0.6	0.4	0.4	0.3
7 & 8 (1.0)	0 – 1	4.8	4.8	4.8	4.8	4.2	3.0	2.5	2.1	1.9	1.6	1.4	1.2
	1.1 – 3	4.8	4.8	4.6	3.7	3.1	2.5	2.2	1.9	1.7	1.5	1.4	1.0
	3.1 – 5	4.8	3.2	3.2	2.8	2.5	2.0	1.8	1.5	1.4	1.4	1.1	1.0
	> 5	3.1	2.6	2.2	2.1	1.9	1.6	1.5	1.4	1.3	1.2	1.0	0.9
9,10,11 & 12	All Design Slopes	(No restrictions within practical design criteria)											

Gilley, J.R., Suitability of Reduced Pressure Center-Pivot. Journal of Irrigation and Drainage, Vol. 110, No. 1, March, 1984. ASAE. Pages 22–34, Table 5.

Allowable soil surface storage values for various slopes, (without artifical storage). (Included in Table 5.2)

Slope (percent)	Allowable soil surface storage, (inches)
0 – 1	0.5
1.1 – 3	0.3
3.1 – 5	0.1
> 5	0.0

Dillon, et al, ASAE Transactions 1972, Pages 996 – 1001, Table 6.

Application rate adjustment for residue other than 2000#

with >4000# residue use 125% of above rate
with 4000# residue use 120% of above rate
with 3500# residue use 115% of above rate
with 3000# residue use 110% of above rate
with 2500# residue use 105% of above rate
with 1500# residue use 95% of above rate
with 1000# residue use 90% of above rate
with <1000# residue use 85% of above rate

2. <u>Moderate Pressure - Revolving Sprinklers</u> - These are usually single nozzle sprinklers with an operating pressure of from 15 to 30 psi, a wetted diameter coverage of 60 to 80 feet and a minimum application rate of 0.20 inch/hour. If revolving sprinklers are used on a center pivot sprinkler system, they generally are moderate pressure sprinklers.

3. <u>Intermediate Pressure - Revolving Sprinklers</u> - This type may be either single or dual nozzle design with operating pressures of 30 to 60 psi and wetted diameter coverage of 75 to 125 feet with a minimum application rate of 0.25 inch per hour. This sprinkler is probably the most popular revolving sprinkler because it can be adapted to a wide variety of soils and crops.

4. <u>High Pressure - Revolving Sprinklers</u> - This type may be either single or dual nozzle design with operating pressures of 50 to 100 psi and providing a wetted diameter coverage of 110 to 230 feet with a minimum application rate of 0.50 inch per hour. Sprinklers of this type are primarily adapted to truck crops, field crops and pastures in areas where distortion of the pattern from wind is not excessive. They provide fast coverage with limited equipment.

5. <u>Hydraulic or Giant - Revolving Sprinklers</u> - These sprinklers have a large nozzle and may have smaller supplemental nozzles to fill in pattern gaps. They operate at pressures of 80 to 120 psi, and they cover a wetted diameter from 200 to 400 feet with a minimum application rate of 0.65 inch per hour. Adaptability is primarily with irrigated pastures or tall growing crops where rapid coverage is desired and acceptable. They are limited to soils with medium or high intake rates.

6. <u>Low Pressure - Fixed Spray Sprinkler</u> - These sprinklers are used in conjunction with center pivot or linear move type sprinkler systems. They operate at 5 to 40 psi with a wetted diameter of 10 to 50 feet depending on the location of the spray nozzle relative to the lateral. The application rate within the system is controlled by the spray nozzle spacing (wetted diameter) and spray nozzle size and is generally high. There are two main types of spray nozzles--a 360-degree spray nozzle or a 180-degree spray nozzle. There are many variations of these nozzles on the market (Low-drift nozzle, Superspray, Rotator, Valley spray, Soft-spray nozzle, Wobbler, etc.) These sprinklers are adapted to any crop that can be irrigated with a center pivot sprinkler on medium and high intake soils.

7. <u>Ultra-low Pressure - Fixed Spray Sprinkler</u> - LEPA (Low Energy Precision Application) nozzles were designed to be used with linear move sprinkler systems and were adapted for use with the center pivot sprinklers. Pressure at the nozzle is 6 to 10 psi with a wetted diameter of 1 to 10 feet depending on the mode of the LEPA nozzle. They are attached to drop lines which are located 8 to 18 inches from the ground. Application rates are

TABLE 5.2a*

Maximum Sprinkler Application Rate - P - (In./Hr.)

For Alfalfa, Grass, or Tilled Crop with 4000# or More Residue

Irrig. Design Group	Design Slope Group	Net Irrigation Application "F" (In.)		
		1.0	1.5	2.0
1&2	0.4 or less	1.2	0.5	0.35
	0.7	0.9	0.45	0.30
	1.5	0.6	0.40	0.25

$F = (aT^b + 0.275)$ $P = (\frac{60F}{T})b$

with the following reduction of intake for surface storage:

Slope 0.4 or less - 0.5"
Slope 0.7 or less - 0.4"
Slope 1.5 or less - 0.3"

For Tilled Crops

with 3500# residue use 95% of the above rate
with 3000# residue use 90% of the above rate
with 2500# residue use 85% of the above rate
with 2000# residue use 80% of the above rate
with 1500# residue use 75% of the above rate
with 1000# residue use 70% of the above rate
with <1000# residue use 65% of the above rate

*NOTE: Use of this table is restricted to special cases where irrigation is limited to frequent light applications and the slope and residue requirements are strictly adhered to.

very high and may approach furrow irrigation rates in the bubble mode. These sprinklers are adapted to any crop that can be irrigated with a center pivot or linear move system. Fields should be relatively flat (0 to 3 percent) or pits or furrow dikes may be required to prevent the water from moving. The nozzles should be used on medium or high intake soils.

C. Types of Systems

All sprinkler irrigation systems use a series of one or more of the above types of nozzles to distribute the water. Water is conveyed to these nozzles through either stationary or movable pipelines, and the operation of these pipelines determines the type of system.

1. Hand-Moved System - The lateral line and sprinklers are set at one location and allowed to remain there until the desired gross amount of water is applied. They are then moved by hand from this position to another and the operation repeated. This is, therefore, a set-type system. Quick-coupled aluminum pipe is the best for most portable laterals. This is generally the cheapest type of system. However, considerable labor is required to move the pipe from set to set. Figure 5-1 shows the general layout and operation of typical set-type distribution systems, one of which is the hand-moved. It also shows the water source in the center of the field although it could be at another point with the main line located through the center of the field.

   When a lateral line reaches the end of the field, it is disassembled and either moved back to its original location or across the main line to the original location of the other lateral. The lateral lines must be moved back to the starting location so that the area which was sprinkled first will again be sprinkled first in the following cycle.

   Generally, to keep the labor costs as low as practical, the design should be such that the required irrigation is applied in either 7-hour or 11-hour time of set to allow either 3 or 2 sets per day with an hour allowed each setting for moving the pipe. No costs are shown for this system nor for others given in this section except in general descriptive terms and in generalized comparisons between systems. The cost of the distribution equipment for hand-moved systems is one of the less expensive of sprinkler distribution systems.

   Advantages and Limitations: The hand-moved system can be used on irregularly shaped fields and rolling terrain. Any nozzle from low to high pressure can be used to meet any intake rate requirement. It is inconvenient and gives poor distribution for tall crops.

2. Side-Roll System - To decrease the amount and intensity of labor required, the lateral line is mounted on wheels. The pipe is

the axle with the wheels usually spaced 30 feet apart and the sprinklers midway between. Wheels are available in different diameters with the largest wheels used for maximum clearance.

The operation of the side-roll lateral is similar to the hand-moved system. The lateral line is moved between sets by rolling the wheels. The distance between lateral sets depends on the size of the sprinklers. Usually the distance will be 60 to 80 feet. The connection of the lateral to the main line is usually made with a 10- to 15-foot section of flexible hose.

Most side-roll systems use an air-cooled gasoline engine located near the center of the line for moving. Some of the older systems use a lever and ratchet method for moving the line. Because the pipe tends to twist somewhat in moving, it is necessary to provide for vertical alignment of the sprinkler. The self-aligner riser is a gooseneck device with a counter weight to keep the sprinkler vertical.

The side-roll system has been modified by some manufacturers by supporting the sprinkler lateral above the wheels of an "A" frame and using a drive shaft to move the system instead of using the pipe as an axle.

To gain greater coverage width for a lateral set, side-roll systems have been developed which use trailing sprinkler lines, each containing 3 or 4 sprinklers. These sprinklers, in addition to the sprinklers located on the main lateral, provide for set distances up to 300 feet. The field operation is the same as a hand-move or the conventional side-roll lateral system except the coverage distance per set is considerably greater. The operation of this system is shown in Figure 5-2.

When the lateral reaches the end of the field, it has to be moved back to the starting point or to an adjacent field and the trailing lines must be picked up and moved separately. Provisions can be made to transport the trailing lines on the main lateral line. These systems often have a main lateral line supported on tower assemblies to provide clearance for tall crops.

The cost of the distribution equipment is moderate to moderately high.

<u>Advantages and Limitations</u>: Can be used on any soil type suitable for sprinkler irrigation. Requires rectangular fields. Except when mounted on tower assemblies, these systems are not adapted to tall crops. Alignment may be difficult on undulating topography.

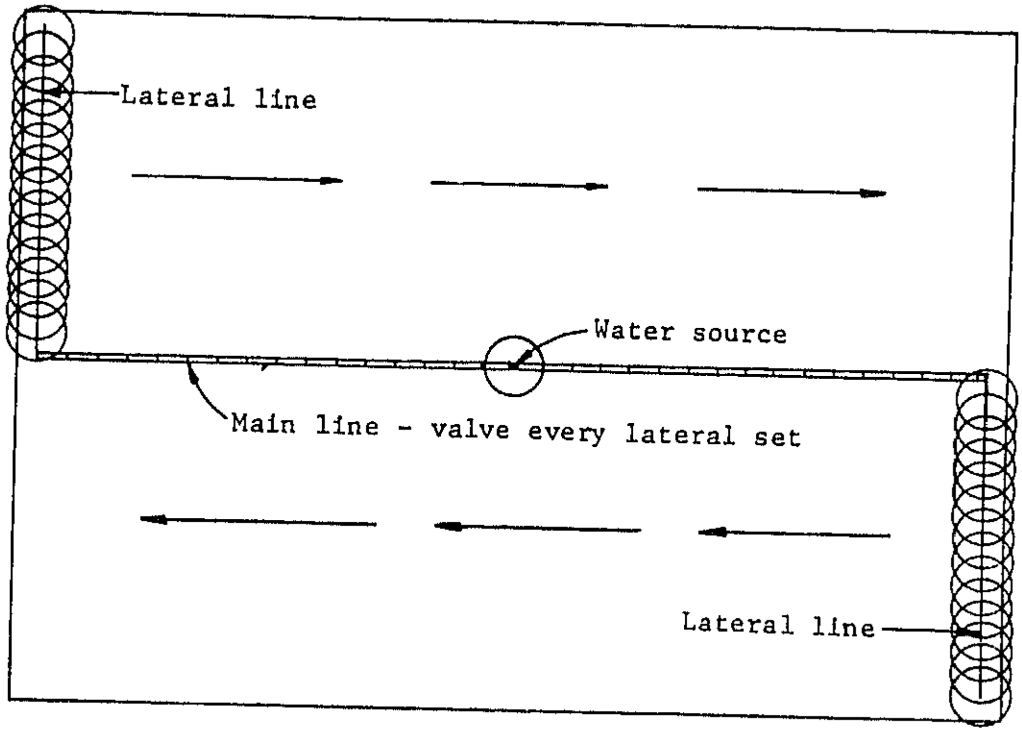


Figure 5-1, Set-type irrigation system

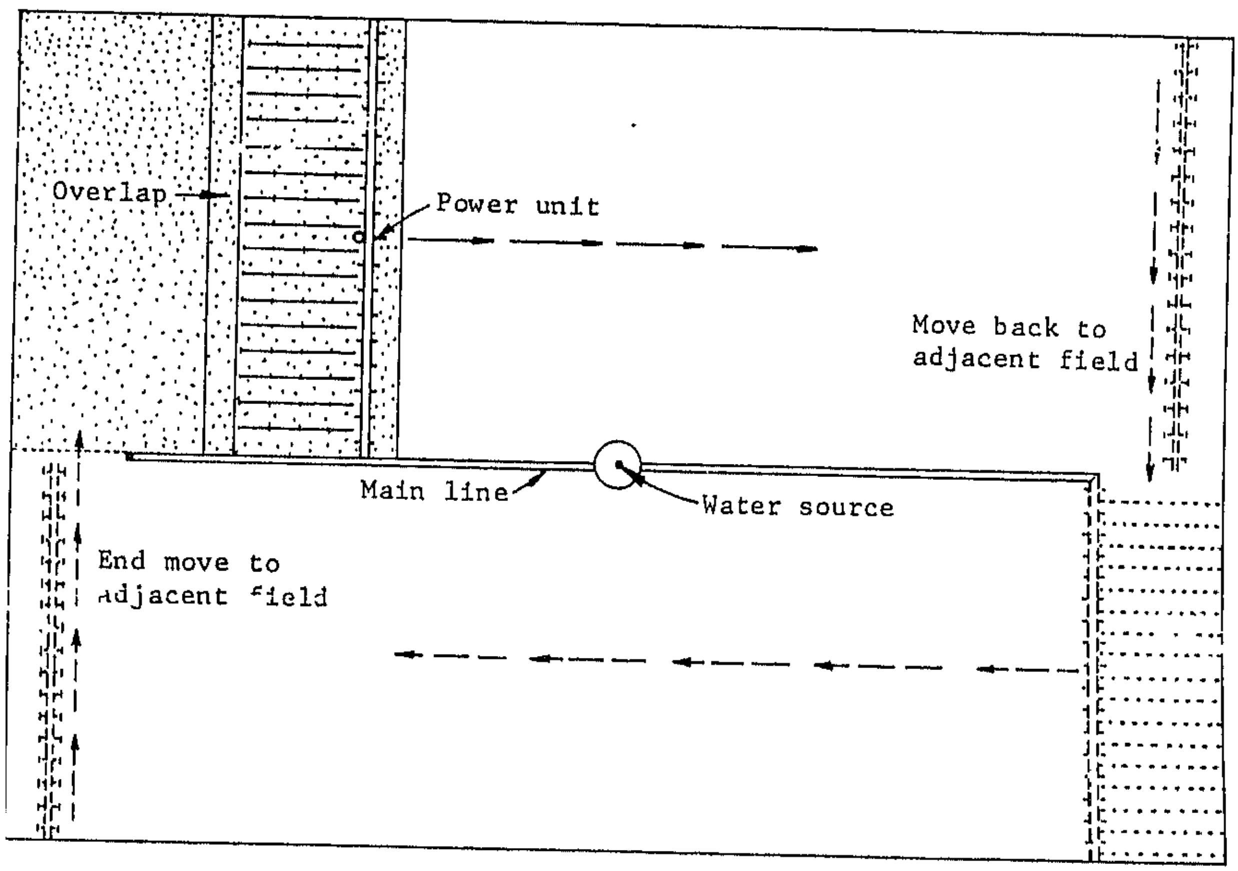


Figure 5-2, Operation of trailing-line system

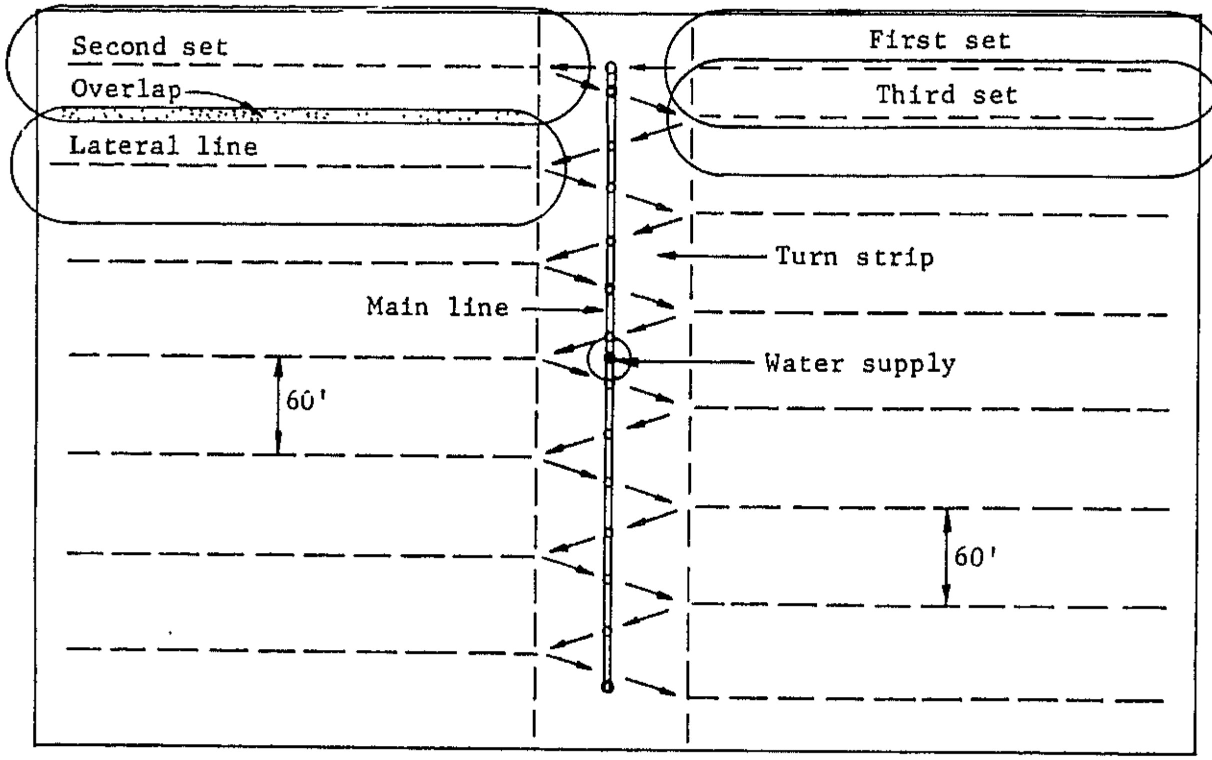


Figure 5-3, End-tow system operation

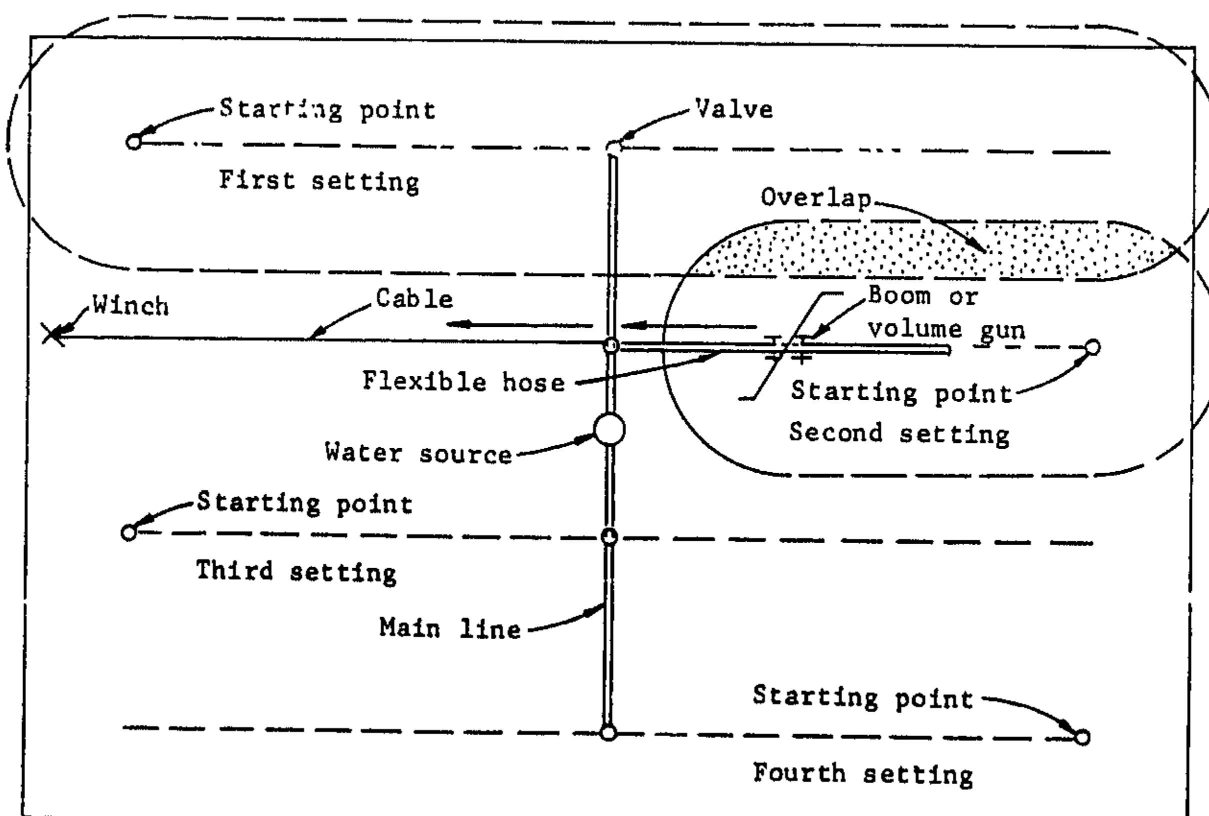


Figure 5-4, Continuous move boom or volume gun

3. <u>End-Tow Lateral System</u> - Another irrigation system using lateral sets is the end-tow or tractor-move system. The lateral line has couplers semi-permanently fastened together. The lateral line may be mounted on skid pans or small wheels to be towed from one set to the next. The operation of a typical end-tow lateral line is shown in Figure 5-3. The main line which supplies the water for the system is located in the center of the field. A turn strip 100 to 200 feet wide is provided so the lateral line can be turned as it is towed from one side of the field to the other. A typical system might have 60-foot sets so the lateral will need to be shifted 30 feet as it crosses the turn strip.

   When the lateral reaches the last setting in the field, it will have to be moved back to the starting position--the location of the first set.

   To keep the sprinkler risers vertical during sprinkling and while the system is being moved, stabilizers are used on the lateral.

   As the lateral is towed across the ground, pipe will wear, depending some on the crop cover and soil texture. Sandy soils which have very rough particles will cause the greatest wear. Tow-line couplers usually provide for turning the pipe to distribute the wear around its circumference.

   The turn strip may be grass or some harvestable crop so that this land is not completely lost to production.

   Generally, design requirements are the same as for hand-moved systems. The cost of the distribution system is generally moderate, being higher than hand-moved systems but less expensive than some other types.

   <u>Advantages and Limitations</u>: This system is adapted to any soil type that is suitable for sprinkler irrigation. Requires 100- to 200-foot turnways and narrow alleyways in irrigated row crop. Rectangular fields are needed.

4. <u>Rotating Boom System</u> - This system consists of pipe and nozzle arms that rotate about the center or balance point located on a 4-wheel mounted turntable. A tower and cable arrangement holds the booms in place. The booms rotate by water pressure using a jet action controlled by various nozzle arrangements, nozzle sizes, and various water pressures. The arms are provided in a choice of lengths that give coverage of about 1 to 4 acres per setting. Application rates vary from about 0.4 to 0.8 inch per hour with the usual rate being approximately 0.5 inch per hour. The unit can be pulled ahead to a new setting by a tractor attached to the boom carriage by a cable that is sufficient so that the tractor operates on dry ground. As the boom moves ahead, feeder pipeline sections can be picked up and placed on

the trailer that supports the boom. Settings should be such that a triangular pattern results with adjacent lanes.

Because of the large wetted diameter coverage there can be a problem with wind distortion of the pattern. Wind also can affect rotation speed of the booms. Under severe conditions the rotation may even stop when the booms reach a position at right angles to the wind. Since water discharges from the nozzle at a uniform rate, any variation in rotation speed will upset the sprinkler distribution pattern. The distance between lanes should be equal to the diameter of the boom plus 70 percent of the difference between wetted diameter and boom diameter.

The average cost of the distribution equipment is generally moderate and similar to the cost of end-tow lateral systems.

Advantages and Limitations: Rotating boom systems can be used on irregularly shaped fields. Wind affects rotation and water distribution. Alleyways are required for row crops. Application rate is too high for some soils.

5. Volume Gun System - The volume gun sprinkler consists of a single high capacity nozzle mounted on a 2- to 4-wheel trailer. The pump and power unit may also be mounted on the equipment, or it may be permanently placed at a central location. In some types, a tractor is used as the power unit. Volume gun sprinklers are usually larger than 3/4-inch diameter, and recommended operating pressures usually exceed 90 pounds per square inch. This pressure will increase the horsepower requirement for the distribution system. When the operating pressure is below the manufacturer's recommendations, the water distribution will be uneven.

   The wetted diameters of volume guns are extremely large compared to the 10 to 15 g.p.m. sprinklers which are often used on lateral lines. Because of the large wetted diameter, it is difficult to obtain proper overlap of the sprinkler patterns. Wind distortion of the pattern is also a factor in trying to accomplish good field-wide water distribution. The distance between the lanes should be approximately 65 percent of the diameter of the wetted area. The sets should be such that a rectangular pattern will result. This gives the best water distribution pattern. The volume gun, being large, can spray liquids containing some sediments so it is well suited for delivering animal liquid wastes from collecting ponds to crop fields.

   The cost of the distribution equipment is, in general, one of the less expensive sprinkler distribution systems.

   Advantages and Limitations: Volume guns can be used on irregularly shaped fields and can distribute water containing small particle sediments. High operating pressure is required. The wind affects water distribution.

Alleyways are required for row crops. Application rates are generally in excess of 0.65 inch per hour and are, therefore, suited only to medium and high intake rate soils.

6. Continuous Move Boom System - With flexible supply hose or open ditch to convey water and either a cable with power winch or a slow moving tractor-powered unit, the sprinkler can operate as it moves along a lane. The speed of sprinkler travel can be varied and is adjusted according to the amount of water to be applied. While the water discharge from the sprinkler nozzles is at a constant rate, the amount of water applied can be varied by the travel speed. The speed also can be adjusted so that moving the hose and sprinkler unit from one lane to the next will fit other farm operations.

   The flexible hose is available in 4-inch and 5-inch diameter sizes. There is considerable friction loss in the hose which must be overcome by pump pressure. This additional pressure requires additional horsepower and increases the operating cost of the system.

   In addition to having sufficient strength to withstand high operating pressures, the hose must be strong enough to be towed when full of water. Thus, a special type hose is needed for the continuous move sprinklers. Wear and abrasion are also important considerations in the use of the hose. Periodic replacement of the hose is a sizable maintenance cost and should be considered in the purchase of this type of system. If water is supplied by an open ditch, seepage losses may be high and field slopes must be such that these ditches are practical to use.

   Figure 5-4 shows the pattern of operation for a boom sprinkler with a continuous move. A winch is anchored at one end of the field and an air-cooled gasoline engine winds up the cable which tows the sprinkler at a continuous rate along the lane through the field. The flexible hose supplies water to the sprinkler from the main line in the center of the field. For a lane length of 1320 feet, about 600 feet of hose is required.

   The distance between the lanes should be approximately equal to the diameter of the boom plus 70 percent of difference between the wetted diameter and the boom diameter. The lane where the sprinkler and hose operate should be smooth and well maintained. The boom sprinkler as it moves through the field should not tilt one way or the other because of an uneven lane. Tilting causes an uneven water distribution pattern.

   Design requirements are the same as for rotating boom in sets. The average cost of the distribution equipment is, in general, moderately high.

Advantages and Limitations: These are the same as for the rotating boom except rectangular fields are desirable, overlap between sets is eliminated (but not overlap between lanes) and friction loss is high in the flexible cable.

7. Continuous Move Volume Gun System (Traveling Gun) - The same type continuous move operation is used with the volume gun as was explained for the boom.

The power to move the sprinkler may be supplied by self-propelled equipment or by a motor mounted on the sprinkler trailer which winds a cable on a drum. Another method has the motor and winch anchored at the end of the field.

On some types of volume gun sprinklers using the continuous move principle, a sprinkler mechanism purposely does not water the lane area directly in front of its travel to keep a firm track for the sprinkler car or trailer.

As with a continuous move boom sprinkler, the overlap pattern between individual sets along the land is eliminated. Therefore, the distribution pattern is better with a continuous move sprinkler than with the same sprinkler set at selected intervals.

The average cost of the distribution equipment is, in general, moderate to moderately high.

Advantages and Limitations: Same as for the volume gun operated at selected sets except rectangular fields are desirable and the flexible hose causes high friction loss.

8. Solid Set System - The solid set system is gaining popularity particularly for high value crops. With this system the main line and the lateral lines remain in place during the growing season. Sometimes the solid set system is permanent with the main line and lateral lines buried. With other solid set systems the pipes are installed in the field after planting and remain there until harvest.

These systems may be used to apply water to meet crop demand and for the purpose of temperature modification either for frost protection or hot weather cooling.

There are two types of solid set systems:

a. All lateral lines are simultaneously operated. This type may be modified to a rapid sequence system where water is applied for approximately 3 minutes to each one-fifth of the area and the irrigated area is covered each 15 minutes until desired application is made. See Figure 5-5.

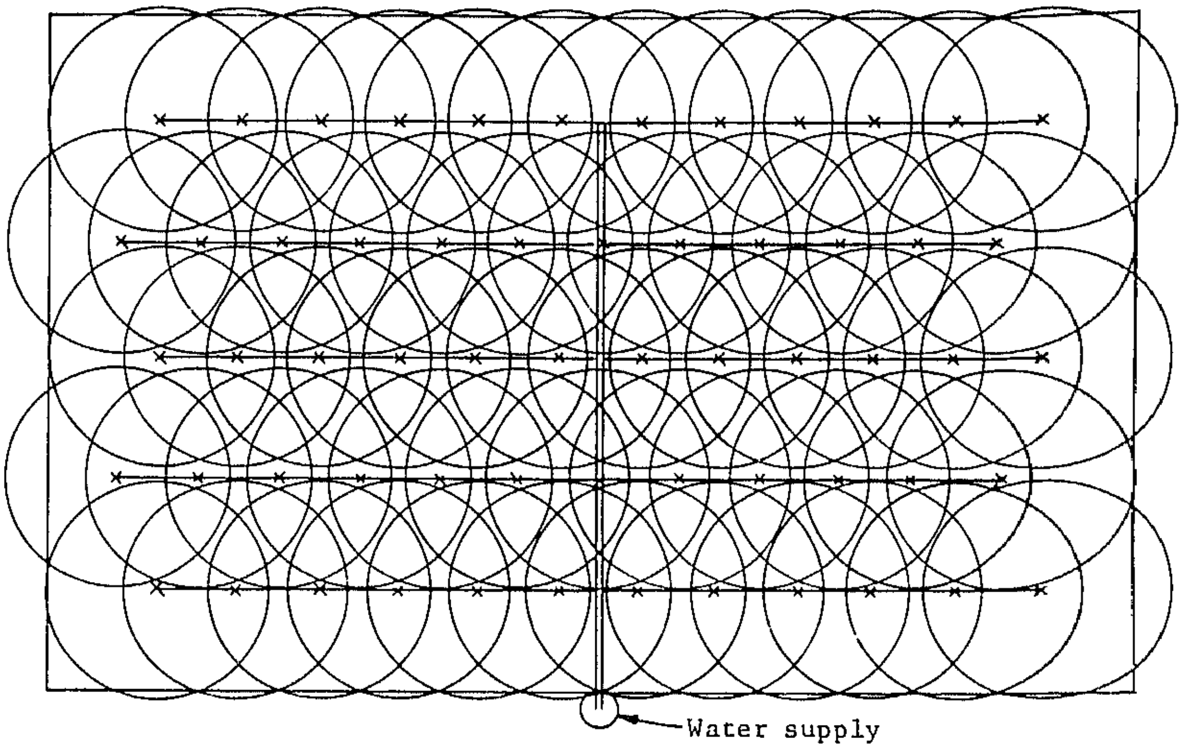


Figure 5-5 A solid set system

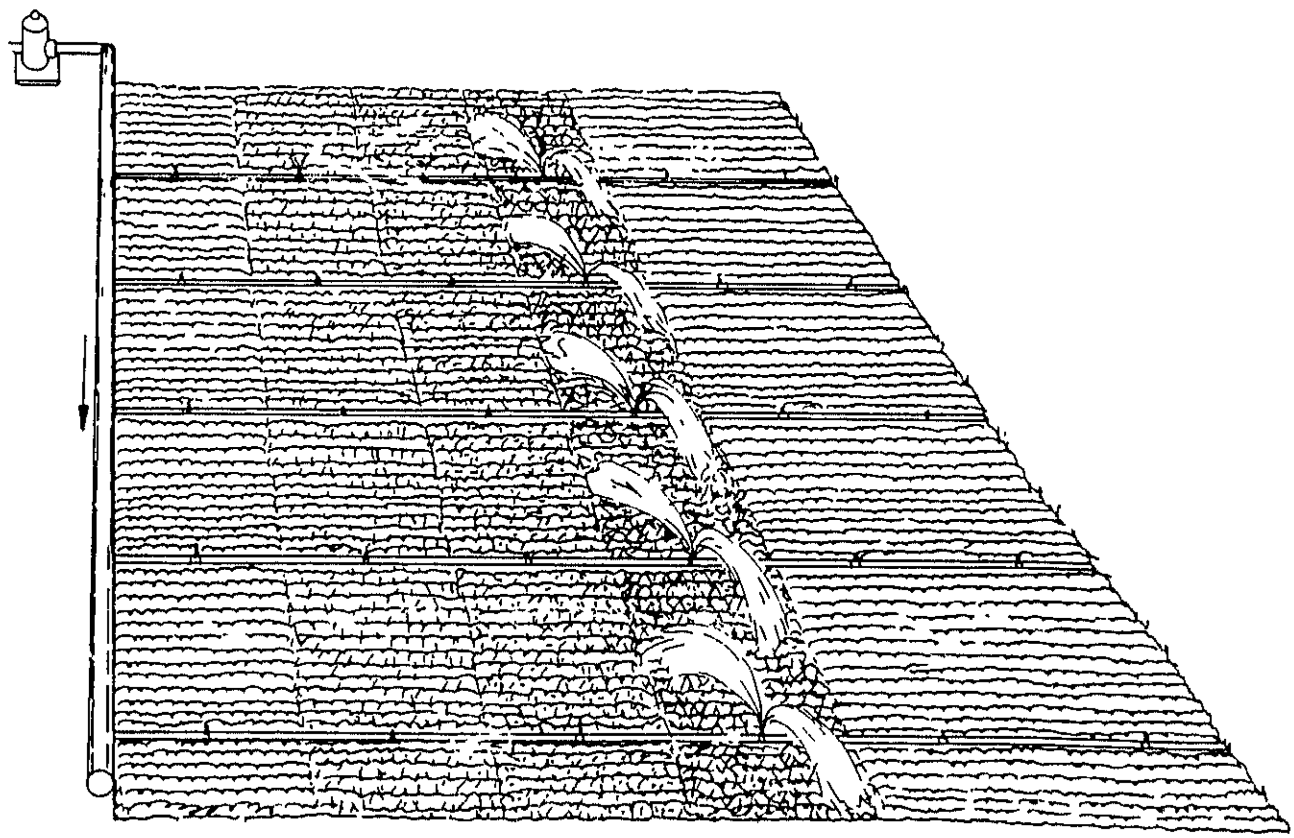


Figure 5-6 Sequencing solid set

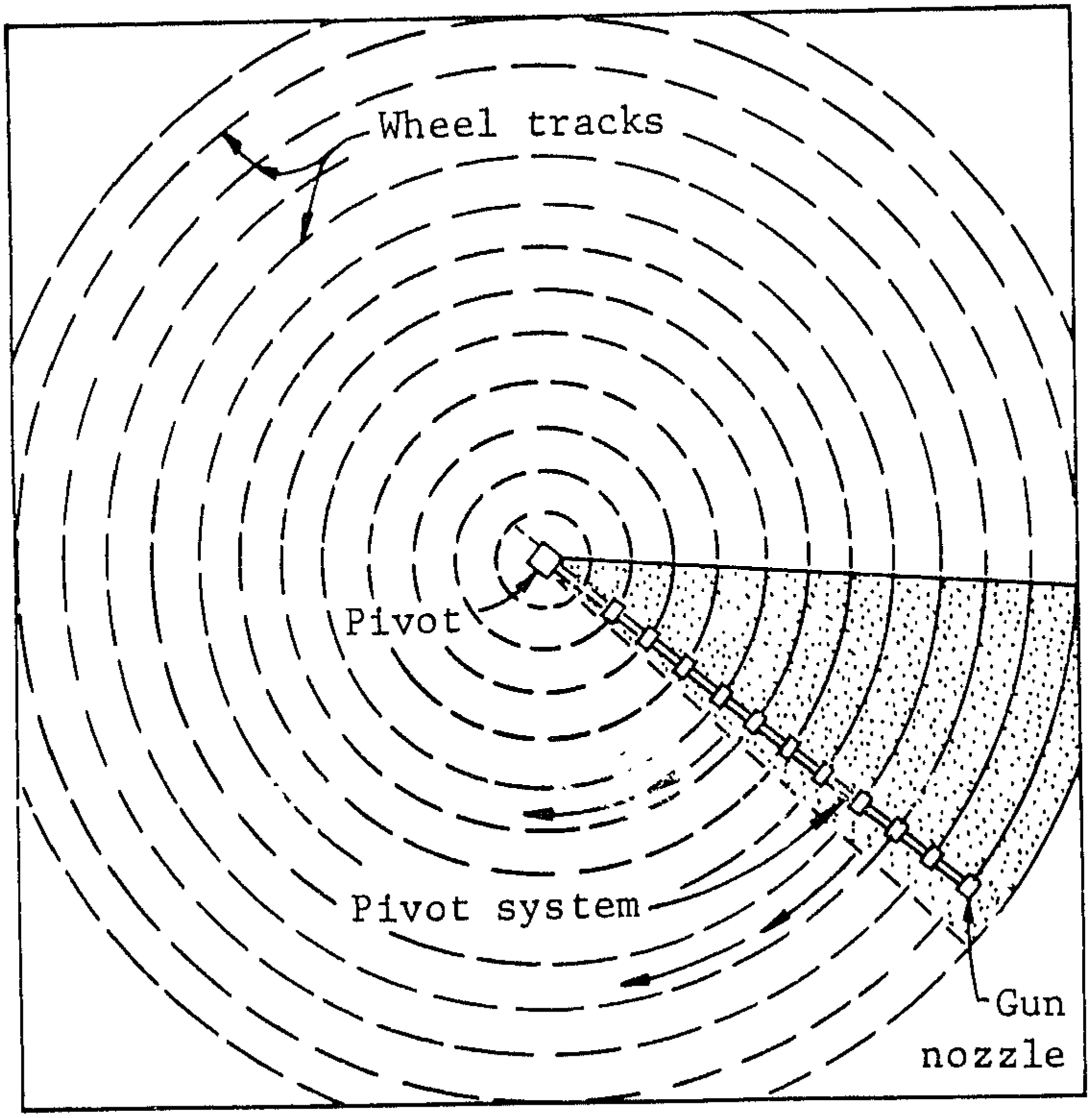


Figure 5-7 A center-pivot. (Gun nozzle used in corners only)

b. The Sequa-Matic system is a group of sprinklers that are operated the required time then automatically shutoff and another group is turned on. This sequence is repeated until the field is irrigated. This type is shown in Figure 5-6.

Average cost of the solid set distribution equipment is generally the most expensive of sprinkler system types.

<u>Advantages and Limitations</u>: The solid set system is adapted to irregular shaped fields. It permits good sprinkler control with minimum labor after installation. Equipment investment cost is high. Lateral lines may interfere with field operations.

9. <u>Center Pivot Self-Propelled System</u> - This system consists of a single lateral mounted on wheels spaced on approximately 150- to 200-foot centers and supported by towers with cable or truss support. Each of the towers has a device to provide power to the wheels. The type of power varies with the manufacturer. It can be provided by water pumped through the system, by hydraulic oil, by an electric motor on each tower, by compressed air or by revolving jets.

The operation of the center pivot system is shown in Figure 5-7. An anchor pivot point is located at the center of the field around which the entire system pivots.

The speed of rotation of the center pivot system may vary from 12 hours to a week or more. The rate or water application is the same, regardless of the speed of rotation. However, the faster the rotation speed, the less total water is applied per rotation. An average rotation speed is approximately 60 to 72 hours per revolution. The amount applied per revolution is approximately 1 inch gross.

The speed of the center pivot sprinkler is usually controlled by the end tower called the master tower. A system of alignment controls keep the other towers in line with the end tower.

With the center pivot system, a circular or square field is required. On a quarter section (160 acres) approximately 122 acres are under irrigation by sprinklers on the line. If an end gun is used to irrigate a part of the corners, then approximately 135 acres are irrigated. End guns usually operate much below specified pressure for that type sprinkler resulting in large drops and uneven distribution. The large drops tend to create soil puddling and greatly increase the chance for water loss by runoff. The area irrigated under the end gun generally produces the poorest yields.

The average cost of the distribution equipment is, in general, higher than for most other systems; but it is less than solid set systems.

Advantages and Limitations: The center pivot system, if kept in good repair, requires a minimum of operating labor. Circular or square fields with no obstructions are required. Application rate is high at the outer end of the line resulting in excess runoff on low intake soils. Required operating pressure varies from 15 to 90 pounds per square inch at the pivot depending on length and diameter of the lateral pipe and on the type of nozzle. There is a tendency for wheels to cut deep ruts in some soils; also, gully erosion in the wheel tracks can be a substantial problem.

10. Linear Move Lateral System - Self-propelled linear move laterals combine the structure and guidance of a center pivot with a traveling water feed system similar to that of a continuous move volume gun. They require rectangular fields free from obstructions for efficient operation. Systems that pump water from open ditches must be installed on nearly level fields. Even if the system is supplied by a flexible hose, the slopes should be moderate in order for the guidance system to work effectively.

The application rate of the water is the same along the lateral. The amount of water applied is dependent on the speed of the system. Generally 1 to 2 inches is applied per pass. With low pressure spray nozzles the application rate can be very high and the speed of the system may have to be increased to keep from producing runoff. The system can be operated similarly to Figures 5-1 or 5-2.

The average cost of the distribution equipment is generally about the same as for the center pivot system.

Advantages and Limitations: The linear move system like the center pivot system requires a minimum of operating labor. The system requires a square or rectangular field and, unlike the center pivot system, can irrigate the entire field. Operating pressures can vary from 15 to 90 psi depending on the type of sprinkler nozzle being used. A major disadvantage of the linear move system as compared to the center pivot system is the problem of bringing the lateral back to the starting position. Since a center pivot operates in a circle, it automatically ends each irrigation cycle at the beginning of the next; but a linear move system has to be driven or towed back to the starting position. Measured water distribution from these systems has the highest uniformity coefficients of any system for single irrigations under windy conditions.

D. DESIGN PROCEDURES

The first step in the design procedure is to collect basic farm resource data. This information includes a topographic map showing obstacles and farm and field boundaries, as well as data on crops, soils, water quality and water quantity. The farmer should be consulted about financial, labor and management capabilities. Once the data on the farm's resources have been assembled, the system selection, layout and hydraulic design process can proceed.

There are four major components in a sprinkler system: sprinklers, laterals, mainline and pumping plant. The design process should begin with the sprinkler selection; continue with the system layout and be followed by the design of the lateral, mainline and pumping plant. To make a rational system selection, it may be necessary to design and analyze two or more systems; and the farmer should carefully study the system ultimately selected.

1. Periodic-Move Sprinkler Systems - The basic strategy for designing all periodic-move systems is the same for fixed and hand-move systems. Much of the design described in this section also applies to continuous-move systems. For example, the design of mainlines and pumping plants is similar for all systems. There are also many similarities between the nozzle characteristics of periodic-move and continuous-move systems. Because of this overlap, the sections on the continuous-move sprinklers will only contain materials that are unique to that system.

   a. Sprinkler Selection - Sprinklers are classified according to their operating pressure range and their position in relation to irrigated crops. The different classifications, with the characteristics and adaptability of each, were mentioned earlier. Actual sprinkler head selection is based on the discharge rate, height of trajectory and sprinkler distribution characteristics desired.

   Once the type of sprinkler has been determined, based on pressure limitations, application rates, cover conditions, crop requirements, and availability of labor, the next step is to determine the combination of sprinkler spacing, operating pressure and nozzle sizes that will most nearly provide the optimum water-application rate with the greatest uniformity of distribution.

   Manufacturers of sprinklers specify a wetted diameter for all nozzle sizes and operating pressure combinations for each type of sprinkler in their line. Since sprinkler-spacing recommendations commonly are made on the basis of these diameters, the designer must carefully consider them. The spacing of sprinklers along the lateral and the spacing of laterals along the mainline should comply with the

spacing requirements as stated in the Kansas Standard for Irrigation System, Sprinkler - 442.

Table 5.12 shows the expected discharges and wetted diameters in conditions of no wind from typical impact sprinklers with angles of trajectory between 22^o and 28^o. For sprinklers with angle of trajectory of 6^o, multiply the wetted diameters in Table 5.12 by 0.85. Table 5.12a shows the expected discharges and wetted diameters in conditions of no wind from typical low pressure spray nozzles.

Sprinkler application rates are based on the sprinkler discharge, the spacing of the sprinklers on the lateral and either the lateral spacing on the mainline or the wetted diameter of the sprinkler. The equation to calculate the sprinkler application rate is:

$$I = \frac{96.3\ q}{s_l\ s_m} \qquad \text{(Equation 1)}$$

where I = average application rate (iph)
q = sprinkler discharge (gpm)
s_l = spacing of sprinklers along the laterals (ft)
s_m = spacing of laterals along mainline or wetted diameter (ft)

Table 5.3 gives the application rate for different sprinkler spacings and sprinkler discharges. Gross irrigation amounts for different net irrigation requirements and design efficiencies are shown in Table 5.4.

b. <u>System Layout</u> - Often the layout of a system will be simple as in the case of small, rectangularly shaped areas. On the other hand, large odd-shaped tracts with broken topography may present a complex engineering problem requiring alternate layouts and careful pipe-size analyses. Sprinkler size and placement, lateral size and placement, mainline size and placement and pumping plant size and placement are all important in the design of a sprinkler system.

c. <u>Laterals</u> - Periodic-move sprinkler systems may have several laterals operating at one time or just one lateral. Either way, the sprinkler systems require the moving of the laterals at specific intervals of time. In order to fit with the farm schedules, it is generally recommended that the time of sets be planned for 7-, 11-, or 23-hour periods of time. This allows for one hour per set for moving the lines and servicing the equipment. The number of settings

required for each lateral depends on the number of allowable sets per day and on the maximum number of days allowed for completing one irrigation during the peak-use period.

To obtain near-uniform application of water throughout the length of a lateral, the line must be of a pipe diameter and length and follow an alignment that will result in a minimum variation in the discharge of individual sprinklers along the line. Normally this variation in discharge should not exceed ±10 percent unless long term economic justification exists. Therefore, either pressure (or flow) regulation must be provided for each sprinkler; or laterals must be located and pipe sizes selected so that the total losses in the line, due to both friction head and elevation, will not exceed 20 percent of the average design operating pressure for the sprinklers.

Friction loss is less for flow through a line with a number of equally spaced outlets than for flow through the length of pipe with no outlets because the volume of flow decreases each time an outlet is passed. A method has been developed by Christiansen for computing the friction losses in multiple-outlet pipelines. The method involves first computing the friction loss in the line without multiple outlets and then multiplying by a factor based on the number of outlets (sprinklers) in the line. Friction losses in portable aluminum pipe laterals with couplings can be determined using Table 5.5. The factor for the multiple outlets is shown in Table 5.6.

d. Mainline - Mainlines for sprinkler systems vary from short, portable feeder lines to intricate networks of buried mains and submains for large systems. The principal function of mainlines and submains is to convey the quantities of water required to all parts of the design area at the pressure required to operate all laterals under maximum flow conditions. The principal design problem is the selection of pipe sizes that will accomplish this function economically. The design of mainlines or submains requires an analysis of the entire system to determine maximum requirements for capacity and pressure.

Table 5.5 shows the friction loss in portable aluminum pipe with couplings. For other tables showing friction loss for various pipe materials, sizes and pressure, refer to Part 9 of the Kansas Irrigation Guide for low head pipe and Exhibit 3-7, Chapter 3, Engineering Field Manual for plastic pipe with working pressure greater than 50 psi.

e. Pumping Plant - To select a pump and power unit that will operate the system efficiently, the pump has to be selected for the amount of water to be pumped and for the total

dynamic head to be pumped against; and the power unit size must be matched to the power required to pump the water. The total dynamic head is the sum of the following: pressure head required to operate nozzles; friction losses in mainline, submains, and laterals; friction losses in fittings and valves; elevation differences in the field and pumping water level below the water discharge. Allowance must be made for friction losses in all elbows, tees, crossings, reducers, increasers, adapters and valves placed in laterals, mainlines, submains and in the suction line. The amount of water to be pumped will depend on well capacity and/or the size of the sprinkler system.

If operating conditions vary considerably with movement of laterals and mainline or with a change in the number of sprinklers operated, both the maximum and minimum total dynamic head must be computed. After determining the range of operating conditions (maximum and minimum capacities and total dynamic heads), the pump and power unit can be selected. One source of information is The National Engineering Handbook, Section 15, Chapter 8, Irrigation Pumping Plants.

f. Design Example

Given: Field is 1290 feet by 2600 feet, 77 acres (80 acres less roads), E 1/2 of SE 1/4, land slope 0.5 to 1.0 percent on Keith silt loam (0.5 intake family). The well, 15 feet inside the east edge of the field centered north to south, supplies 750 gpm at 65 psi. Average crop residue is 2000 pounds per acre or better.

The irrigator desires 7- or 11-hour settings using a side-roll sprinkler system with 50- by 60-foot sprinkler and lateral spacing. The crop is alfalfa. Mainline is 1230 feet long and laterals are 1300 feet long north and south of the mainline. The field is nearly level.

(1) Determine Net and Gross Application - The crop will be irrigated when the available soil moisture in the root zone has been depleted by 50 percent. Use a root zone of 4 feet for alfalfa. Keith silt loam is in design group 5. Part 3 of the Kansas Irrigation Guide (Soils) shows that the available waterholding capacity for the top 4 feet of Keith soils is 9.4 inches. Fifty percent of this is 4.7 inches. This would be the maximum net irrigation. Consider 4.0 to 4.5 inches in planning the system.

(2) Determine the Sprinkler Size - The side-roll would be 1300 feet long to fit the field. Sprinkler nozzle spacing at 50 feet requires 26 nozzles (1300 ÷ 50 = 26). To distribute 750 gpm the nozzle capacity would

Table 5.3a

Minimum Gross Irrigation Requirements for Sprinkler

For July-August (62-Day) Period - At 70% Efficiency

Based on 50% Chance Rainfall

In block: Top figure = Inches per day; Bottom figure = g.p.m. per acre (continuous application)

Crop	Tribune	Colby	Ulysses	Ness City	Stockton	Greensburg	Ellsworth	Concordia	Wichita	Council Grove	Holton	Chanute	Paola
Alfalfa	.243 4.6	.236 4.4	.247 4.7	.221 4.2	.215 4.1	.232 4.4	.221 4.2	.204 3.8	.205 3.9	.179 3.4	.182 3.4	.174 3.3	.148 2.8
Corn	.245 4.6	.240 4.5	.248 4.7	.236 4.4	.222 4.2	.244 4.6	.224 4.2	.200 3.8	.213 4.0	.176 3.3	.162 3.1	.157 3.0	.111 2.1
Sorghum	.229 4.3	.228 4.3	.233 4.4	.220 4.1	.205 3.9	.230 4.3	.200 3.8	.178 3.4	.173 3.3	.136 2.6	.108 2.0	.104 2.0	.069 1.3
Tame Grass	.223 4.2	.213 4.0	.226 4.3	.209 3.9	.196 3.7	.213 4.0	.205 3.9	.188 3.5	.187 3.5	.156 2.9	.163 3.1	.151 2.8	.124 2.3
July 15 to Sept. 15 Soybeans	.223 4.2	.216 4.1	.227 4.3	.206 3.9	.187 3.5	.214 4.0	.185 3.5	.160 3.0	.150 2.8	.108 2.0	.085 1.6	.074 1.4	.041 0.8
Sugar Beets	.245 4.6	.245 4.6	.247 4.7	.238 4.5									

Table 5.4

Minimum Gross Irrigation Requirements for Sprinkler

For July-August (62-day) Period - At 75% Efficiency

Based on 80% Chance Rainfall

In block: Top figure = Inches per day; Bottom figure = g.p.m. per acre (continuous application)

Crop	Tribune	Colby	Ulysses	Ness City	Stockton	Greensburg	Ellsworth	Concordia	Wichita	Council Grove	Holton	Chanute	Paola
Alfalfa	.245 4.6	.238 4.5	.250 4.7	.236 4.4	.226 4.3	.239 4.5	.230 4.3	.217 4.1	.222 4.2	.205 3.9	.207 3.9	.204 3.8	.187 3.5
Corn	.247 4.7	.243 4.6	.250 4.7	.242 4.6	.233 4.4	.246 4.6	.230 4.3	.215 4.1	.223 4.2	.199 3.8	.191 3.6	.188 3.5	.166 3.1
Sorghum	.231 4.4	.230 4.3	.237 4.5	.226 4.3	.222 4.2	.235 4.4	.223 4.2	.201 3.8	.205 3.9	.179 3.4	.163 3.1	.157 3.0	.129 2.4
Tame Grass	.226 4.3	.217 4.1	.227 4.3	.215 4.1	.207 3.9	.219 4.1	.216 4.1	.200 3.8	.205 3.9	.184 3.5	.190 3.6	.186 3.5	.166 3.1
July 15 to Sept. 15 Soybeans	.227 4.3	.222 4.2	.230 4.3	.217 4.1	.210 4.0	.223 4.2	.218 4.1	.190 3.6	.188 3.5	.166 3.1	.150 2.8	.142 2.7	.112 2.1
Sugar Beets	.253 4.8	.251 4.7	.255 4.8	.249 4.7									

be 28.8 gpm (750 ÷ 26 = 28.8). From Table 5.12, a 3/8-inch nozzle will discharge 28.8 gpm at 54 psi with a 156-foot wetted diameter. The minimum lateral spacing from the Kansas Standard for Irrigation, Sprinkler - 442 is 50 percent of the wetted diameter for winds to 10 mph. Fifty percent of 156 is 78 feet, the lateral spacing of 60 feet is acceptable.

To calculate the average application rate while the side-roll system is operating, use Equation 1. Use q = 28.8 gpm, a sprinkler spacing of 50 feet, and a wetted diameter of 156 feet. This gives a rate of 0.36 inch per hour. To calculate the total precipitation applied per set, again use the equation for average application rate. For q = 28.8 gpm and a spacing of 50 by 60 feet the application rate is .92 inch per hour. For a 7-hour set the gross irrigation is 6.44 inches and for an 11-hour set the gross is 10.12 inches. Use the 7-hour set. From Table 5.1 the estimated application efficiency is 70 percent. 6.44 inches x 0.7 = 4.5 inches net application.

From Table 5.2 (0.5 intake family and 0 to 1 percent slope) a net application of 4.5 inches will permit a maximum application rate of 0.6 iph for a field with 2000 pounds of residue. Therefore, an application rate of 0.36 iph is acceptable.

(3) <u>Determine Size of Lateral</u> - Allowable variation in sprinkler lateral is 20 percent of design pressure. For a sprinkler pressure of 54 psi the allowable loss in the line is 10.8 psi or 24.95 feet. Lines are 1300 feet long, spacings of nozzles are 50 feet with 26 nozzles per line. Factor F, Table 5-6, for outlets in the middle = .36. For a multiple outlet line, the theoretical allowable pressure loss in feet per 100 feet of lateral would be head loss divided by factor F. 24.95 ÷ (13 x .36) = 5.33 feet per 100 feet of lateral.

From Table 5.5 a 5-inch lateral line carrying 750 gpm would have a friction loss of 11.74 feet per 100 feet of lateral which is excessive. A 6-inch lateral line would have a friction loss of 4.81 feet per 100 feet of lateral which is well within the allowable friction loss of 5.33 feet. So a 6-inch lateral line is required.

TABLE 5.3

Table of Precipitaion – Inches per hour

Spacing (feet)	Gallons per Minute from Each Sprinkler														
	2	3	4	5	6	7	8	9	10	11	12	15	18	20	25
30x30	0.21	0.32	0.43	0.54	0.64	0.75	0.86	0.96							
30x40	0.16	0.24	0.32	0.40	0.48	0.56	0.64	0.72	0.80	0.88	0.96				
30x50		0.19	0.26	0.32	0.39	0.45	0.51	0.58	0.64	0.71	0.77	0.96			
30x60			0.21	0.27	0.32	0.37	0.43	0.48	0.54	0.59	0.64	0.80	0.96		
40x40		0.18	0.24	0.30	0.36	0.42	0.48	0.54	0.60	0.66	0.72	0.90			
40x50			0.19	0.24	0.29	0.34	0.39	0.43	0.48	0.53	0.58	0.72	0.87	0.96	
40x60				0.20	0.24	0.28	0.32	0.36	0.40	0.44	0.48	0.60	0.72	0.80	1.00
50x50				0.19	0.23	0.27	0.31	0.35	0.39	0.42	0.46	0.58	0.69	0.77	0.96
50x60					0.19	0.22	0.26	0.29	0.32	0.35	0.39	0.48	0.58	0.64	0.80
50x70						0.19	0.22	0.25	0.28	0.30	0.33	0.41	0.50	0.55	0.69
60x60							0.21	0.24	0.27	0.29	0.32	0.40	0.48	0.54	0.67
60x70								0.21	0.23	0.25	0.28	0.34	0.41	0.46	0.57
60x80									0.20	0.22	0.24	0.30	0.36	0.40	0.50

TABLE 5.4

Gross Irrigation Application (Inches) for Design Efficiency

Net Irrig. Depth, Inches	Design Efficiency (Percent)							
	95	90	85	80	75	70	65	60
0.50	0.53	0.56	0.59	0.63	0.67	0.71	0.77	0.83
0.75	0.79	0.83	0.88	0.94	1.00	1.07	1.15	1.25
1.00	1.05	1.11	1.18	1.25	1.33	1.43	1.54	1.67
1.25	1.32	1.39	1.47	1.56	1.67	1.79	1.92	2.08
1.50	1.58	1.67	1.76	1.88	2.00	2.14	2.31	2.50
1.75	1.84	1.94	2.06	2.19	2.33	2.50	2.69	2.92
2.00	2.11	2.22	2.35	2.50	2.67	2.86	3.08	3.33
2.25	2.35	2.50	2.65	2.81	3.00	3.21	3.46	3.75
2.50	2.63	2.78	2.94	3.13	3.33	3.57	3.85	4.17
2.75	2.89	3.06	3.24	3.44	3.67	3.93	4.23	4.58
3.00	3.16	3.33	3.53	3.75	4.00	4.29	4.62	5.00
3.25	3.42	3.61	3.82	4.06	4.33	4.64	5.00	5.42
3.50	3.68	3.89	4.12	4.38	4.67	5.00	5.38	5.83
3.75	3.95	4.17	4.41	4.69	5.00	5.36	5.77	6.25
4.00	4.21	4.44	4.71	5.00	5.33	5.71	6.15	6.67
4.25	4.47	4.72	5.00	5.31	5.67	6.07	6.54	7.08
4.50	4.74	5.00	5.29	5.63	6.00	6.43	6.92	7.50
4.75	5.00	5.28	5.59	5.94	6.33	6.79	7.31	7.92
5.00	5.26	5.56	5.88	6.25	6.67	7.14	7.69	8.33

Table 5.4a

Minimum Gross Irrigation Requirements for Sprinkler

For July-August (62-day) Period - At 75% Efficiency

Based on 50% Chance Rainfall

In block: Top figure = Inches per day; Bottom figure = g.p.m. per acre (continuous application)

Crop	Tribune	Colby	Ulysses	Ness City	Stockton	Greensburg	Ellsworth	Concordia	Wichita	Council Grove	Holton	Chanute	Paola
Alfalfa	.226 4.3	.220 4.1	.230 4.3	.206 3.9	.200 3.8	.217 4.1	.206 3.9	.190 3.6	.192 3.6	.167 3.1	.170 3.2	.162 3.1	.138 2.6
Corn	.229 4.3	.224 4.2	.232 4.4	.220 4.1	.207 3.9	.228 4.3	.209 3.9	.187 3.5	.199 3.8	.165 3.1	.151 2.8	.147 2.8	.103 1.9
Sorghum	.214 4.0	.213 4.0	.217 4.1	.205 3.9	.191 3.6	.214 4.0	.187 3.5	.166 3.1	.162 3.1	.127 2.4	.101 1.9	.097 1.8	.065 1.2
Tame Grass	.208 3.9	.199 3.8	.211 4.0	.195 3.7	.183 3.4	.199 3.8	.192 3.6	.175 3.3	.175 3.3	.146 2.8	.152 2.9	.141 2.7	.115 2.2
July 15 to Sept. 15 Soybeans	.208 3.9	.202 3.8	.212 4.0	.193 3.6	.175 3.3	.200 3.8	.172 3.2	.149 2.8	.140 2.6	.101 1.9	.080 1.5	.069 1.3	.039 0.7
Sugar Beets	.229 4.3	.229 4.3	.231 4.4	.222 4.2									

Table 5.5

Amount of Increase in "g.p.m. per Acre" Above the Value in Tables 5.3. 5.3a. 5.4 and 5.4a Required to Offset Low Available Water Capacity

Irrigation Group	Dry Years 80% Chance	Normal Years 50% Chance
3 through 9	No change	No change
10	No change	+ 0.2 g.p.m.
11	+ 0.1 g.p.m.	+ 0.3 g.p.m.
12	+ 0.2 g.p.m.	+ 0.5 g.p.m.

2. Irrigation Application Rate and Soil Intake Rate - A principle of sprinkler irrigation design is that application rate must not exceed the intake rate of the soil. It is for this reason that sprinkler irrigation is not recommended for soils in the 0.1 intake family. With center pivot systems, this principle may be difficult to accomplish on 0.3 intake family soils and to some extent on the 0.5 intake family soils, particularly if large irrigation applications are made. Management features that can be used to increase effective soil intake rate are (1) maintain a ground cover of crop residue during the irrigation period (the heavier the better) up to about 4000 pounds per acre, (2) make light and frequent applications (for example, about one inch gross application about each 2½ to 3 days), and (3) reduce effective slope by contour operations or leveling. Note that Table 5.2 gives data that takes into account these management features.

3. Other Center Pivot System Design Considerations - Table 5.6 (Center Pivot Component and Area Relationships), Table 5.7 (Nozzle Discharge in g.p.m. and Average Wetted Diameter for Sprinkler Nozzles) and Table 5.8 (Pressure Loss on Center Pivot Systems) contain information that is usually needed in center pivot design determinations or evaluation assessment.

   The following are factual items that generally apply to center pivot design considerations.

   (a) Distance of travel for a circular operating system is 6.28 times the system length from the pivot to the outside drive wheel.

TABLE 5.5

Friction Loss in Feet per 100 Feet in Lateral and Main Lines of Portable Aluminum Pipe With Couplings[1]

Flow rate (gpm)	4-inch[2] (0.050) (3.900)	5-inch (0.050) (4.900)	6-inch (0.058) (5.884)	8-inch (0.072) (7.856)	10-inch (0.091) (9.818)
100	0.85	0.28	0.12	0.03	0.01
120	1.20	0.39	0.16	0.04	0.01
140	1.59	0.52	0.22	0.05	0.02
160	2.04	0.67	0.28	0.07	0.02
180	2.54	0.83	0.34	0.08	0.03
200	3.08	1.01	0.42	0.10	0.03
220	3.68	1.21	0.50	0.12	0.04
240	4.32	1.42	0.58	0.14	0.05
260	5.01	1.65	0.68	0.17	0.06
280	5.75	1.89	0.78	0.19	0.06
300	6.54	2.15	0.88	0.22	0.07
320	7.37	2.42	0.99	0.24	0.08
340	8.24	2.71	1.11	0.27	0.09
360	9.16	3.01	1.24	0.30	0.10
380	10.13	3.33	1.37	0.33	0.11
400	11.14	3.66	1.50	0.37	0.12
420	12.19	4.01	1.64	0.40	0.14
440	13.28	4.37	1.79	0.44	0.15
460	14.42	4.75	1.95	0.48	0.16
480	15.61	5.14	2.11	0.52	0.17
500	16.83	5.54	2.27	0.56	0.19
550	20.08	6.61	2.71	0.66	0.22
600	23.59	7.76	3.18	0.78	0.26
650	27.37	9.00	3.69	0.90	0.31
700	31.39	10.33	4.24	1.04	0.35
750	35.67	11.74	4.81	1.18	0.40
800	40.20	13.23	5.42	1.33	0.45
850	44.97	14.80	6.07	1.49	0.50
900	50.00	16.45	6.75	1.65	0.56
950	55.26	18.18	7.46	1.83	0.62
1000	60.77	19.99	8.20	2.01	0.68

[1] Based on Hazen-Williams formula (From NEH 15, Equation 11-15 for C = 130) and 30-foot pipe lengths; 20-foot pipe increase by 7% and 40-foot pipe decrease by 3%.

[2] Outside diameter; wall thickness and inside diameter in parentheses.

TABLE 5.6

Reduction Coefficients (F) For Computing
Friction Loss in Pipe With Multiple Outlets[1]

Number of Outlets	F[2] (end)	F[3] (mid)
1	1.00	1.00
2	0.64	0.52
3	0.53	0.44
4	0.49	0.41
5	0.46	0.40
6	0.44	0.39
7	0.43	0.38
8	0.42	0.38
9	0.41	0.37
10-11	0.40	0.37
12-14	0.39	0.37
15-20	0.38	0.36
21-35	0.37	0.36
>35	0.36	0.36

[1] Based on Christiansen's formula (from NEH-15, Chapter 11, equations 11-16a and 11-16b)

[2] F(end) is for 1st sprinkler at far end of first pipe joint.

[3] F(mid) is for 1st sprinkler at middle of first pipe joint.

TABLE 5.7

Amount of Increase in "gpm per Acre" Above the
Value in Tables 5.8, 5.8a, 5.9, and 5.9a Required
to Offset Low Available Water Holding Capacity

Irrigation Group	Dry Years 80% Chance	Normal Years 50% Chance
1 through 9	No change	No change
10	No change	+0.2 gpm
11	+0.1 gpm	+0.3 gpm
12	+0.2 gpm	+0.5 gpm

t. Find allowable application rate, inches/hour in Table 5.2 or 5.2a..

u. Actual application = (G.A. ÷ $\frac{\text{W.D.}}{\text{T.S.}}$) 60 in inches/hr.

v. The actual application rate should not exceed the allowable rate found in Item t.

5. Center Pivot Sprinkler Design Example - Use Form KS-EN-22 (Rev.). See Table 5.5a. Given: Location is Ulysses area. The soil is Ulysses silt loam, (intake family 0.5, design group 5). The crop is corn with a usual residue of 1,000 pounds. Land slope is 2-3 percent and water supply (well) is 675 g.p.m. Pipe diameter is 6 inches; system length is 1,300 feet; the distance from pivot to outer drive wheel (D) is 1,250 feet; and there is no end gun. There are three 5/16" x 7/32" nozzles on the outer 100 feet of line. Travel speed (T.S.) at the outer wheel is 1.5 feet/min. Area irrigated is 121.9 acres with estimated efficiency of 70 percent. Pivot pressure (P_p) is 75 p.s.i. and Q at the pivot is 675 g.p.m.

Pressure loss (P_L) from Table 5.8, is 15 p.s.i. for 1,300 feet of 6-inch diameter line at 675 g.p.m. Pressure at outer end = 75-15 = 60 p.s.i. Q, 675 g.p.m. ÷ acres irrigated, 121.9 = 5.54 g.p.m./ac. This meets the "80 percent chance" gross minimum requirement of 5.1 g.p.m./ac. for corn from Table 5.3. Percent of water delivered to the outer 100 feet of line = 14.8 percent (Table 5.6). 675 x 0.148 = 99.9 g.p.m. in outer 100 feet of line. 99.9 g.p.m. ÷ no. of nozzles in outer 100 feet, 3 = 33.3 g.p.m. per outer nozzle. Using nozzle size selected above,

5/16" @ 60 p.s.i. = 22.0 g.p.m. (Table 5.7)
7/32" @ 60 p.s.i. = 10.7 g.p.m. (Table 5.7)
Total = 32.7 g.p.m. per sprinkler

Wetted diameter (W.D.) of larger nozzle (5/16") @ p.s.i. = 145 feet (Table 5.7). A commerical 5/16" x 7/32" nozzle is rated at 31.7 g.p.m. with a 148-foot W.D. Also, should work at about 65 p.s.i. for highest efficiency.

Travel Distance (T.D.) = 6.28 x D = 6.28 x 1,250' = 7,850'
Revolution Time (R.T.) = T.D. ÷ (T.S. x 60) = 7,850 ÷ (1.5 x 60) = 87.2 hours
Gross Application = $\frac{Q}{450} \times \frac{R.T.}{A} = \frac{675}{450} \times \frac{87.2}{121.9}$ = 1.07 inches

Net Application = G.A. x efficiency = 1.07" x 70% = 0.75"
Maximum allowable application rate, Table 5.2, for 0.5 intake family, 3% slope, (use 1.0" net application) = 1.5"/hr. less 30% for 1,000-pound residue condition = 1.5 x (100% - 30%) = 1.05"/hr. = Maximum rate

Actual application rate = $(G.A. \div \frac{W.D.}{T.S.})\ 60 = (1.07 \div \frac{145}{T.5})\ 60 = 0.66''/hr.$

Which is within allowable maximum of 1.05"/hr.
Application rate 0.5"/hr. - Reference Table 5.1, efficiency = 70%, O.K. with original estimate.

6. Center Pivot Sprinkler System - Field Evaluation - Field evaluation can be done whenever the system is operating. It becomes increasingly difficult when the height of crop increases beyond 3 to 4 feet.

Procedure: Use Form KS-EN-22a (See Table 5.5b)

a. Record soil type, design group, land slope, crop, and pounds of crop residue per acre.

b. List the temperature, estimated wind velocity, and humidity.

c. Check the soil moisture conditions in the root zone of the crop using a soil probe or spade. Make estimates of the available moisture and the percentage of field capacity. Note special conditions such as dry zones.

d. Note water source and measured Q in g.p.m. into the system. If a flow meter is not available, use the procedure outlined in Item 4c on page 5-23 under Center Pivot Design or Operation Evaluation.

e. Record the system dimensions and acres irrigated (see Table 5.6).

f. Set two stakes in line with the outer drive wheel, 50 to 100 feet apart. Record the travel time between the two stakes in minutes. Travel speed (T.S.) in feet per minute is equal to the distance traveled in feet divided by the time in minutes.

g. Travel distance in feet for the full circle (T.D.) equals distance from the pivot to the outer drive wheel (D) in feet times 6.28. Travel time, in hours, equals travel distance (T.D.) in feet divided by travel speed (T.S.) in feet per minute times 60. Divide this by 24 to give travel time in days.

h. Check two or more nozzles for excess wear. The size or sizes are stamped on the side of the nozzle. Record the location, nozzle size, the pressure readings taken with a pitot tube and pressure gage. Measure and record the flow from each nozzle in g.p.m. This flow should compare closely with the g.p.m. shown in Table 5.7 for the pressure and nozzle measured. Observe the water intake, especially near the outer end of the system. Appreciable ponding of water or runoff during and after the system has passed will result in poor efficiency and possible crop damage.

i. Set gages or cans ahead of the area being irrigated as shown at the top of page 3 of Form KS-EN-22a. Begin with Station 0+00 at the pivot with the first gage or can set at Station 2+00. Set the containers from that point on even spacings of 30-, 40-, or 60-foot intervals. Set the gages or cans upright and above the crop canopy. Use two heavy rubber bands to secure the gage or can to the stake. Quart oil cans may be used after removing any excess oil with detergent washing.

j. After the system has passed over the gages or cans and no more water is entering them, read and measure the amount caught. If oil cans are used, obtain a graduated cylinder to measure the cubic centimeters (c.c.) caught. Quart oil cans are sized so 200 c.c. equals one inch. Multiply the c.c. caught by 0.005 to obtain the water depth in inches. Record this information in the appropriate table on page 2 of Form KS-EN-22a.

k. Check the maximum application rate near the end of the system but out of range of the end gun. Use the following procedure and the sketch on page 3 of Form KS-EN-22a as a guide in measuring the maximum application rate:

(1) Place five or six stakes, evenly spaced 15 to 20 feet apart, on a line parallel to the travel direction of the system.

(2) Attach gages or cans to the stakes as nearly as possible at the same time.

(3) Leave the containers on the stakes for 5 to 10 minutes. Use a stop watch.

(4) Remove the gages or cans as nearly as possible at the same time. Record their position in the set.

(5) Measure and record the catch in the table at the bottom of page 3 of Form KS-EN-22a. The application rate (in./hr.) is equal to the inches caught times 60 divided by the minutes for the set. The gage or can with the greatest depth will give the maximum measured rate.

l. <u>Computations</u>:

(1) <u>Page 2</u> - Finish the table and compute weighted average depth in inches as follows:

(a) The depth of water in each gage or can is multiplied by an appropriate factor which is a proportion of the area represented by each gage or can. For example, refer to the sample Form KS-EN-22a (Table 5.5b) on page 5-24h.

Note container No. 1 at Station 2+00 is given a factor of 1. Then the factors are uniformly increased to 2.0 at container No. 5 (Station 4+00). No. 5 represents twice the area as No. 1, then the factors increase to 3.0 at container No. 9 (Station 6+00) which represents three times the area as No. 1, and so on. After listing the factors, complete the table by multiplying the factor (F) times the respective inches (I) and then total the factor (F) and I x F columns.

(b) Divide the sum of I x F's by the sum of the factors (F) to obtain the Weighted Average Depth (in.).

(2) Page 2 - Weighted Low Average Depth - Compute as follows:

(a) This is the average depth over the one-fourth of the field receiving the least water. Divide the sum of factors by 4. This will indicate approximately the sum of factors needed for this representation. Start with the can receiving the least amount of water, proceed to greater depths until as near as possible the one-fourth factor amount is reached.

(b) Compute the weighted low average depth the same as for the weighted average depth.

(3) Page 3 - Compute theoretical maximum application rate as follows:

(a) Average application rate (in./hr.) equals the weighted depth (in.) times the travel speed (T.S.) in ft./hr. divided by the wetted diameter in feet.

(b) The theoretical maximum rate (in./hr.) will be 1.5 times the average application rate. (See Item 3d, page 5-23, Kansas Irrigation Guide.)

(4) Page 4 -

(a) Finish the computations as shown on the sample Form KS-EN-22a, Table 5.5b.

(b) Determine from test data whether system is operating within acceptable limits.

(c) Make any needed recommendations or comments as indicated by the field evaluation.

USDA
SCS

KS-EN-22
Rev. 3/79
(File Code ENG-19)

TABLE 5.5a

CENTER PIVOT SPRINKLER
DESIGN OR OPERATION EVALUATION

Owner Example Field Office ____

Legal Descr. ____ Plan No. ____

Note: Design data from Part 5 of the Kansas Irrigation Guide.

Soil Ulysses silt loam Intake family 0.5 Design group 5

Crop Corn Residue 1,000 lbs.; Land slope 2-3 %

Water supply 675 gpm; Pipe dia. 6 in.; Line length, L 1,300 ft.

Distance from pivot to outer drive wheel, D 1,250 ft.

End gun used (corners) (continuous) (not used); Q_g — gpm

Number and size of nozzles on outer 100 ft. of line 3, 5/16" x 7/32"

Travel speed, T.S. 1.5 ft./min. (at the outside drive wheel)

Area irrigated by line L 121.9 ac. (Table 5.6); Efficiency 70 %

Pivot pressure, P_p 75 p.s.i.; Q at the pivot, Q_p 675 gpm

Pressure loss in line, P_L 15 p.s.i. (Table 5.8); Pressure at end of line = $P_p - P_L$ = 75 - 15 = 60 p.s.i.; Water supply 675 gpm ÷ area irrigated 121.9 ac. = 5.5 gpm/ac. - actual.

Minimum gross irrigation requirement (continuous application) - Tables 5.3, 5.3a, 5.4, 5.4a = 5.1 gpm/ac. Note: actual gpm/ac. must equal or exceed this. If short, reduce acres or increase water supply.

From Table 5.6, percent of total gpm delivered to outer 100 foot of line = 14.8 % x total gpm 675 = 99.9 ÷ no. of nozzles in outer 100 ft. 3 = 33.3* gpm/nozzle, Q_n. from Table 5.7, a 5/16" nozzle, Q = 22.0 gpm, and a 7/32" nozzle, Q = 10.7 gpm

Total for both nozzles = 32.7* gpm, Q_s.

* Total for nozzle(s) Q_s should equal or exceed gpm, Q_n.

Wetted diameter, W.D. of larger nozzle = 145 ft. (Table 5.7)

Travel distance, T.D. = 6.28 x distance from pivot to outer wheel, D,

1,250 ft. = 7,850 ft. Revolution time, R.T. = T.D. 7,850

ft. ÷ (T.S. 1.5 ft./min. x 60) = 87.2 hrs.

Gross application, G.A. = $\frac{Q}{450} \times \frac{R.T.}{A.} = \frac{675}{450} \times \frac{87.2}{121.9} =$ 1.07 in.

Net application = G.A. 1.07 in. x efficiency 70 % = 0.75 in.

Maximum allowable application rate for specified intake group,

slope, and residue = 1.05 *in./hr. (Table 5.2 or 5.2a)

Actual applic. rate = $(G.A. \div \frac{W.D.}{T.S.}) \times 60 = (1.07 \div \frac{145}{1.5})\ 60 =$ 0.66 in./hr.

Note: Application rate must not exceed the maximum allowable rate.

System is or is not operating within acceptable limits (circle one).

Comments or Recommendations: Soil profile should be filled to field

capacity early in the season.

* The system is designed and being operated to meet the objectives

of sound irrigation water management. Yes ✓ No ____

Acres of irrigation water management. 122

Evaluation by Example Date ____

Title ____

Note: Tables referred to are listed in the Kansas Irrigation Guide.

* 1.5"/hr. (4000# residue) x 0.7 = 1.05"/hr. adjusted rate

** Complete if operation evaluation is being made.

CENTER PIVOT SPRINKLER FIELD EVALUATION

Owner Example Field Office ____

Legal Descr. ____ Plan No. ____

Soil Keith silt loam Design Group 5 Land Slope < 0.7 %

Crop Corn Residue 2,000 lbs./ac.

Temperature 85°F Wind 5-10 mph Humidity Low - 15-20%

Soil Moisture 50% of Field Capacity

Water Supply Well Measured Q 900 g.p.m.

Type of System Electrogator - Reinke Mfg. Inc.

Operation Data: End Gun – (Not Used) (Corners) (Continuous)

Remarks End gun not operating during evaluation

System Dimensions

Distance, Pivot to Tower No. 1 164 ft., Tower Spacing variable ft.

End Tower to End 40 ft., Total System Length 1,292 ft.

Distance, D to Outer Drive Wheel 1,252 ft.

Acres Irrigated 132.4 (Table 5.6 – Kansas Irrig. Guide).

Travel Speed, T.S., (100 ÷ Travel Time, minutes) 100 ÷ 80.2 = 1.25 ft./min.

Travel Distance, T.D. = 6.28 x D 1,252 ft. = 7,863 ft.

Travel Time = T.D. ÷ (T.S. x 60) = 7,863 ÷ (1.25 x 60) = 104.8 hrs.

4.4 days

Nozzle Data

Location	Nozzle Size	Pressure, p.s.i.	Measured g.p.m.	Table 5.7 g.p.m.
3+04	13/64"	58	8.9	9.1
6+96	13/64" x 13/64"	54	17.5	17.6
12+02	13/64" x 15/64"	46	18.6	19.4

CONTAINER DATA

Sta.	Can No.	C.C.*	Inches I.	Factor F.	I. x F.
2+00	1	180	0.90	1.0	0.9
25	2	188	0.94	1.125	1.058
50	3	236	1.18	1.25	1.475
75	4	158	0.79	1.375	1.086
3+00	5	238	1.19	1.5	1.785
25	6	184	0.92	1.625	1.495
50	7	234	1.17	1.75	2.048
75	8	244	1.22	1.875	2.288
+00	9	246	1.23	2.0	2.46
25	10	238	1.19	2.125	2.529
50	11	238	1.19	2.25	2.678
75	12	238	1.19	2.375	2.826
+00	13	280	1.40	2.5	3.5
25	14	236	1.18	2.625	3.098
50	15	220	1.10	2.75	3.025
75	16	238	1.19	2.875	3.421
+00	17	236	1.18	3.0	3.54
25	18	236	1.18	3.125	3.688
50	19	236	1.18	3.25	3.835
75	20	224	1.12	3.375	3.78
+00	21	236	1.18	3.5	4.13
25	22	252	1.26	3.625	4.568
50	23	248	1.24	3.75	4.65
75	24	248	1.24	3.875	4.805
+00	25	236	1.18	4.0	4.72
25	26	236	1.18	4.125	4.868
50	27	236	1.18	4.25	5.015
75	28	246	1.23	4.375	5.381
+00	29	250	1.25	4.5	5.625
25	30	248	1.24	4.625	5.735
50	31	250	1.25	4.75	5.938
75	32	276	1.38	4.875	6.738
+00	33	300	1.50	5.0	7.5
25	34	286	1.43	5.125	7.329
50	35	270	1.35	5.25	7.088
75	36	272	1.36	5.375	7.31
+00	37	270	1.35	5.5	7.425
25	38	288	1.44	5.625	8.1
50	39	300	1.50	5.75	8.625
75	40	276	1.38	5.875	8.108
·00	41	240	1.20	6.0	7.2
25	42	262	1.31	6.125	8.024
50	43	270	1.35	6.25	8.438
75	44	272	1.36	6.375	8.67
·00	45	270	1.35	6.5	8.775
			Sum	168.75	215.28

0.005 = inches

Container spacing 25 ft.

Pivot to Container No. 1 200 ft.

Hr./Rev. 104.8 hr.

Weighted Ave. Depth:

$$\frac{\text{Sum I x F}}{\text{Sum F}} = \frac{215.28}{168.75}$$

$$= 1.28 \text{ in.}$$

Weighted Low Ave. Depth:

Sum F for 1/4 Area

$$\frac{\text{Sum F}}{4} = \frac{168.75}{4} = 42.188$$

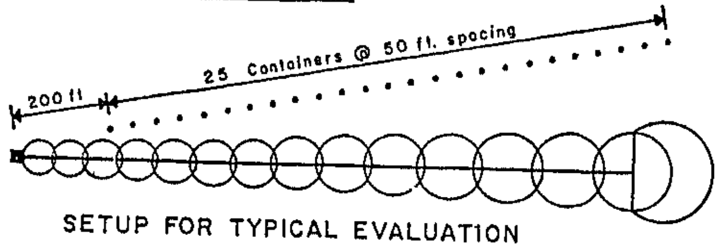
Can No.	Inches I_1	Factor F_1	I_1 x F_1
4	0.79	1.375	1.086
1	0.90	1.0	0.90
6	0.92	1.625	1.495
2	0.94	1.125	1.058
15	1.10	2.75	3.025
20	1.12	3.375	3.78
7	1.17	1.75	2.048
3	1.18	1.25	1.475
14	1.18	2.625	3.098
17	1.18	3.0	3.54
18	1.18	3.125	3.688
19	1.18	3.25	3.835
21	1.18	3.5	4.13
25	1.18	4.0	4.72
26	1.18	4.125	4.868
27	1.18	4.25	5.015
	Sum	42.125	47.761

$$\frac{\text{Sum } I_1 \times F_1}{\text{Sum } F_1} = \frac{47.761}{42.125}$$

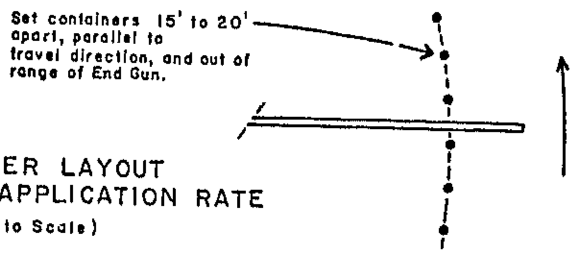
$$= 1.13 \text{ in.}$$

(Continue Computations on Page 4)

C-P SPRINKLER EVALUATION



SETUP FOR TYPICAL EVALUATION



CONTAINER LAYOUT
FOR MAXIMUM APPLICATION RATE
(Not to Scale)

MAXIMUM APPLICATION RATE

Location, Sta. 12+40 Can Spacing 15 ft.

Can No.	Cubic Centi.	Inches	In./Hr.
1	0	0	0
2	20	0.10	1.0
3	25	0.125	1.25
4	22	0.11	1.1
5	18	0.09	0.9
6	0	0	0

Set Time 6 min., Max. Applic. 0.125 in.

Rate = $\frac{\text{Inches Caught}}{\text{Minutes Set}}$ X 60 = $\frac{0.125}{6}$ X 60 = 1.25 in./hr.

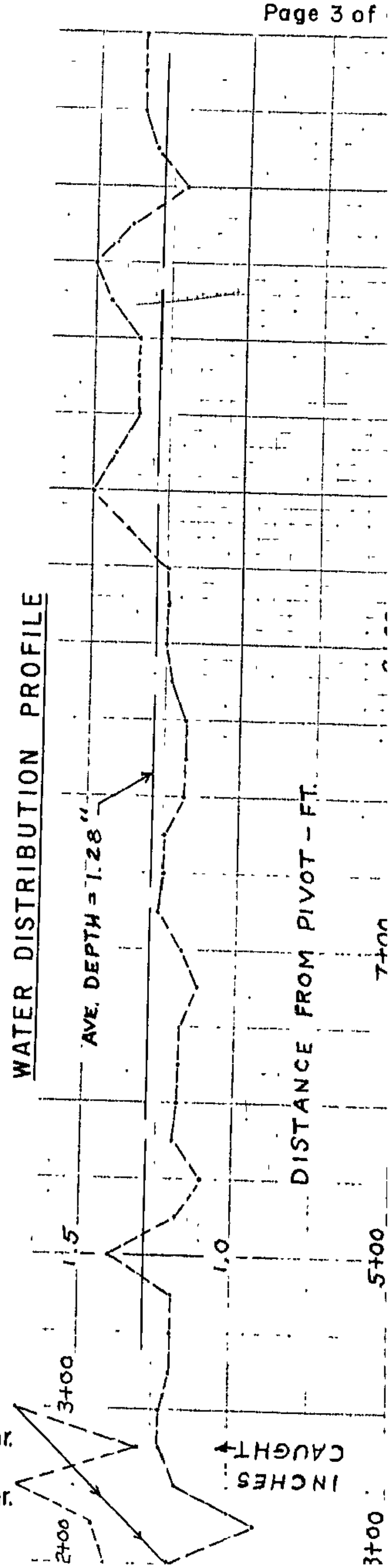
THEORETICAL MAXIMUM APPLICATION RATE

Ave. Depth = 1.28 in.; Travel Speed, T.S. = 75 ft./hr.
(From page 2)

Wetted Diameter, W.D. = 118 ft. (from tables)

Ave. Applic. Rate = $\frac{\text{Ave. Depth X T.S.}}{\text{W.D.}}$ = $\frac{1.28 \times 75}{118}$ = 0.81 in./hr.

Max. Applic. Rate = 1.5 X Ave. Rate = 1.5 X 0.81 = 1.22 in./hr.



COMPUTATIONS AND SUMMARY

Name Example

Date ______

From Page 2:

Pattern Efficiency:

$$\frac{\text{Weighted Low Ave. Depth (in.)} \times 100}{\text{Weighted Ave. Depth (in.)}} = \frac{1.13 \times 100}{1.28} = 88.3\ \%$$

Gross Depth Pumped:

$$\frac{(\text{G.P.M.})(\text{Hr./Rev.})}{450 \times \text{Acres}} = \frac{(900)(104.8)}{450 \times 132.4} = 1.58\ \text{in.}$$

Application Efficiency:

$$\frac{\text{Weighted Ave. Depth (in.)} \times 100}{\text{Gross Depth Pumped (in.)}} = \frac{1.28 \times 100}{1.58} = 81\ \%$$

System Efficiency:

$$\frac{\text{Application Eff. (\%)} \times \text{Pattern Eff. (\%)}}{100} = 81 \times 88.3 \div 100$$

$$= 71.5\ \%$$

Maximum Allowable Application Rate (Table 5.2 OR 5.2a) = 1.44 * in./hr.

Maximum Application Rate (Page 3), Measured = 1.25 in./hr.

Computed = 1.22 in./hr.

* 1.8" x 0.8

System is or is not operating within Acceptable Limits (circle one).

Comments or Recommendations: Soil profile should be filled to field capacity early in the season. Check nozzles at Sta's 2+50 to 3+00, 10+00, 11+50 & 12+00

System Evaluation By Example

Title ______

Date ______

(4) Determine Size of Mainline - When the side-roll is at the west end of the field the water will have to flow through the entire 1230 feet of pipe and the friction losses are the greatest. The pressure at the entrance to the lateral should be the average sprinkler pressure plus half of the friction loss in the lateral or 54 + 4.9 or 58.9 psi. With 65 psi at the pump and 58.9 psi at the lateral, the pressure loss in the mainline should not exceed 6.1 psi or 14.09 feet or 1.15 feet per 100 feet. From Table 5.5, 8-inch pipe will have a loss of 1.18 feet per 100 feet at 750 gpm. This is a reasonable solution for economical pipe size for the mainline.

(5) Determine if System will Meet Crop Need - 750 gpm divided by 450 = 1.67 acre-inches per hour. Three 7-hour sets is 1.67 times 21 or 35.07 acre-inches per day. Field has 77 acres. 35.07 divided by 77 = .455 inch per day gross and at 70 percent efficiency is .455 times 0.7 or .319 inch per day net application.

From Table 2.5, page 2-22, peak consumptive use for corn under 4.5 inches net application is 0.295 inch per day. The system is adequate to meet peak consumptive.

(6) Determine Time to Cover Field - With one side-roll in operation 42 sets are required to cover the field at three settings per day. Time to irrigate the field is 42 divided by 3 which equals 14 days.

2. Center Pivot Sprinkler System - Center pivot self-propelled sprinkler systems are unique in that the rate of speed and also the rate of water application must increase as distance from the pivot point is increased. Therefore, there is no one application rate for these systems. If a large gun type nozzle is used at the outside end of the line, then the irrigation in this outer fringe results in an application rate that is entirely separate from that of the remaining system.

The operating characteristics of the center pivot
purposes of the Kansas Irrigation Guide can be eva
determining the gross application and applicatio
area at the outer 100 feet of the late
designed, the application will b
area irrigated by the lateral li
rate of application will decreas
system. Therefore, the rate of a
if the rate at the outer 100 feet
limitations.

TABLE 5.8

Minimum Gross Irrigation Requirment for Sprinkler
For July–August (62–day) Period – At 75% Efficiency
Based on 80% Chance Rainfall

Location	Crop					
	Alfalfa	Corn	Sorghum	Tame Grass	Soybeans	Wheat
Tribune	0.245 4.6	0.247 4.7	0.231 4.4	0.226 4.3	0.227 4.3	0.170 3.2
Colby	0.238 4.5	0.243 4.6	0.230 4.3	0.217 4.1	0.222 4.2	0.162 3.1
Ulysses	0.250 4.7	0.250 4.7	0.237 4.5	0.227 4.3	0.230 4.3	0.176 3.3
Ness City	0.236 4.4	0.242 4.6	0.226 4.3	0.215 4.1	0.217 4.1	0.159 3.0
Stockton	0.226 4.3	0.233 4.4	0.222 4.2	0.207 3.9	0.210 4.0	0.149 2.8
Greensburg	0.239 4.5	0.246 4.6	0.235 4.4	0.219 4.1	0.223 4.2	0.162 3.1
Ellsworth	0.230 4.3	0.230 4.3	0.223 4.2	0.216 4.1	0.218 4.1	0.138 2.6
Concordia	0.217 4.1	0.215 4.1	0.201 3.8	0.200 3.8	0.190 3.6	0.125 2.4
Wichita	0.222 4.2	0.223 4.2	0.205 3.9	0.205 3.9	0.188 3.5	0.119 2.3
Council Grove	0.205 3.9	0.199 3.8	0.179 3.4	0.184 3.5	0.166 3.1	0.107 2.0
Holton	0.207 3.9	0.191 3.6	0.163 3.1	0.190 3.6	0.150 2.8	0.105 2.0
Chanute	0.204 3.8	0.188 3.5	0.157 3.0	0.186 3.5	0.142 2.7	0.084 1.6
Paola	0.187 3.5	0.166 3.1	0.129 2.4	0.166 3.1	0.112 2.1	0.069 1.3

Top figure = inches per day; Bottom figure = gpm per acre (continuous application).
Soybeans from July 15 to September 15.
Wheat numbers are for April and May.

For irrigation groups 10, 11, and 12 refer to Table 5.7 for adjustment factors.
Use 80% chance tables for most center pivot sprinkler designs.

TABLE 5.8a

Minimum Gross Irrigation Requirment for Sprinkler
For July–August (62–day) Period – At 75% Efficiency
Based on 50% Chance Rainfall

Location	Crop					
	Alfalfa	Corn	Sorghum	Tame Grass	Soybeans	Wheat
Tribune	0.226 4.3	0.229 4.3	0.214 4.0	0.208 3.9	0.208 3.9	0.155 2.9
Colby	0.220 4.1	0.224 4.2	0.213 4.0	0.199 3.8	0.202 3.8	0.145 2.7
Ulysses	0.230 4.3	0.232 4.4	0.217 4.1	0.211 4.0	0.212 4.0	0.159 3.0
Ness City	0.206 3.9	0.220 4.1	0.205 3.9	0.195 3.7	0.193 3.6	0.140 2.7
Stockton	0.200 3.8	0.207 3.9	0.191 3.6	0.183 3.4	0.175 3.3	0.116 2.2
Greensburg	0.217 4.1	0.228 4.3	0.214 4.3	0.199 3.8	0.200 3.8	0.129 2.4
Ellsworth	0.206 3.9	0.209 3.9	0.187 3.5	0.192 3.6	0.172 3.2	0.105 2.0
Concordia	0.190 3.6	0.187 3.5	0.166 3.1	0.175 3.3	0.149 2.8	0.090 1.7
Wichita	0.192 3.6	0.199 3.8	0.162 3.1	0.175 3.3	0.140 2.6	0.082 1.6
Council Grove	0.167 3.1	0.165 3.1	0.127 2.4	0.146 2.8	0.101 1.9	0.056 1.1
Holton	0.170 3.2	0.151 2.8	0.101 1.9	0.152 2.9	0.080 1.5	0.047 0.9
Chanute	0.162 3.1	0.147 2.8	0.097 1.8	0.141 2.7	0.069 1.3	0.009 0.1
Paola	0.138 2.6	0.103 1.9	0.065 1.2	0.115 2.2	0.039 0.7	0.000 0.0

Top figure = inches per day; Bottom figure = gpm per acre (continuous application).
Soybeans from July 15 to September 15.
Wheat numbers are for April and May.

For irrigation groups 10, 11, and 12 refer to Table 5.7 for adjustment factors.
Using 50% chance tables may result in substantially reduced yields during dryer years.

TABLE 5.9

Minimum Gross Irrigation Requirment for Sprinkler
For July-August (62-day) Period - At 85% Efficiency
Based on 80% Chance Rainfall

Location	Crop					
	Alfalfa	Corn	Sorghum	Tame Grass	Soybeans	Wheat
Tribune	0.217 4.1	0.218 4.1	0.204 3.8	0.198 3.7	0.200 3.8	0.151 2.8
Colby	0.210 3.9	0.214 4.0	0.204 3.8	0.191 3.6	0.196 3.7	0.143 2.7
Ulysses	0.221 4.1	0.221 4.1	0.208 3.9	0.201 3.8	0.203 3.8	0.155 2.9
Ness City	0.208 3.9	0.213 4.0	0.199 3.7	0.191 3.6	0.191 3.6	0.140 2.6
Stockton	0.198 3.7	0.205 3.8	0.196 3.7	0.183 3.4	0.183 3.4	0.131 2.5
Greensburg	0.212 4.0	0.217 4.1	0.208 3.9	0.194 3.6	0.199 3.7	0.142 2.7
Ellsworth	0.204 3.8	0.203 3.8	0.197 3.7	0.189 3.5	0.187 3.5	0.105 2.0
Concordia	0.192 3.6	0.189 3.5	0.177 3.3	0.176 3.3	0.167 3.1	0.110 2.1
Wichita	0.196 3.7	0.197 3.7	0.180 3.4	0.181 3.4	0.166 3.1	0.105 2.0
Council Grove	0.180 3.4	0.175 3.3	0.158 3.0	0.166 3.1	0.146 2.7	0.094 1.8
Holton	0.183 3.4	0.169 3.2	0.144 2.7	0.168 3.2	0.133 2.5	0.093 1.7
Chanute	0.180 3.4	0.166 3.1	0.138 2.6	0.162 3.0	0.125 2.3	0.074 1.4
Paola	0.165 3.1	0.147 2.8	0.114 2.1	0.147 2.8	0.099 1.9	0.061 1.4

Top figure = inches per day; Bottom figure = gpm per acre (continuous application).
Soybeans from July 15 to September 15.
Wheat numbers are for April and May.

For irrigation groups 10, 11, and 12 refer to Table 5.7 for adjustment factors.
Use 80% chance tables for most center pivot sprinkler designs.

TABLE 5.9a

Minimum Gross Irrigation Requirment for Sprinkler
For July-August (62-day) Period - At 85% Efficiency
Based on 50% Chance Rainfall

Location	Crop					
	Alfalfa	Corn	Sorghum	Tame Grass	Soybeans	Wheat
Tribune	0.200 3.8	0.202 3.8	0.189 3.5	0.184 3.5	0.184 3.5	0.137 2.6
Colby	0.194 3.6	0.198 3.7	0.188 3.5	0.175 3.3	0.178 3.3	0.128 2.4
Ulysses	0.203 3.8	0.204 3.8	0.192 3.6	0.186 3.5	0.187 3.5	0.140 2.6
Ness City	0.182 3.4	0.194 3.6	0.181 3.4	0.172 3.2	0.170 3.2	0.124 2.3
Stockton	0.177 3.3	0.183 3.4	0.169 3.2	0.161 3.0	0.154 2.9	0.102 1.9
Greensburg	0.191 3.6	0.201 3.8	0.189 3.5	0.175 3.3	0.176 3.3	0.114 2.1
Ellsworth	0.182 3.4	0.184 3.5	0.165 3.1	0.169 3.2	0.152 2.9	0.093 1.7
Concordia	0.168 3.2	0.165 3.1	0.147 3.3	0.155 2.9	0.132 2.5	0.079 1.5
Wichita	0.169 3.2	0.175 3.3	0.142 3.2	0.154 2.9	0.124 2.3	0.072 1.4
Council Grove	0.147 3.3	0.145 2.7	0.112 2.1	0.128 2.4	0.089 1.7	0.049 0.9
Holton	0.150 2.8	0.133 2.5	0.089 1.7	0.134 2.5	0.070 1.3	0.042 0.8
Chanute	0.143 2.7	0.129 2.4	0.086 1.6	0.124 2.3	0.061 1.1	0.009 0.2
Paola	0.122 2.3	0.091 1.7	0.057 1.1	0.102 1.9	0.034 0.6	0.000 0.0

Top figure = inches per day; Bottom figure = gpm per acre (continuous application).
Soybeans from July 15 to September 15.
Wheat numbers are for April and May.

For irrigation groups 10, 11, and 12 refer to Table 5.7 for adjustment factors.
Using 50% chance tables may result in substantially reduced yields during dryer years.

TABLE 5.8b

Minimum Gross Irrigation Requirment for Sprinkler
Based on 75% Efficiency

Location	80% Chance Rainfall			50% Chance Rainfall	
	Dry Beans	Sunflowers		Dry Beans	Sunflowers
Tribune	0.249 4.7	0.228 4.3		0.203 3.8	0.176 3.3
Colby	0.219 4.1	0.215 4.0		0.168 3.2	0.161 3.0
Ulysses	0.273 5.1	0.260 4.9		0.230 4.3	0.202 3.8

TABLE 5.9b

Minimum Gross Irrigation Requirment for Sprinkler
Based on 85% Efficiency

Location	80% Chance Rainfall			50% Chance Rainfall	
	Dry Beans	Sunflowers		Dry Beans	Sunflowers
Tribune	0.220 4.1	0.201 3.8		0.179 3.4	0.156 2.9
Colby	0.193 3.6	0.190 3.6		0.149 2.8	0.142 2.7
Ulysses	0.241 4.5	0.230 4.3		0.203 3.8	0.178 3.3

Top figure = inches per day; Bottom figure = gpm per acre (continuous application).
Dry Beans for the period of June and July.
Sunflowers for the period of July and August.

For irrigation groups 10, 11, and 12 refer to Table 5.7 for adjustment factors.
Use 80% chance tables for most center pivot sprinkler designs.
Using 50% chance tables may result in substantially reduced yields during dryer years.

a. Irrigation Requirement - Center pivot systems frequently do not provide sufficient water to satisfy peak daily consumptive use of the crop without either (1) relying on major withdrawal of soil moisture from the root zone or (2) allowing application rates to exceed soil intake rates, particularly on the lower intake rate soil, thus producing excessive runoff which in turn causes erosion and wastes water and pumping power.

To adjust to this situation, irrigation design philosophies of long standing are modified to provide only sufficient irrigation water to satisfy average daily consumptive use (rather than peak) for the 62-day period of July and August (April and May for wheat) and simultaneously assume benefits from 50 percent chance monthly rainfall (rather than, say, 80 percent chance). For the dryer-than-average years, the use of this modified design criteria will likely result in crop moisture stress and reduced yields unless stored soil moisture is adequate to make up all of the moisture deficiency.

Tables 5.8 and 5.8a (75 percent efficiency) and Tables 5.9 and 5.9a (85 percent efficiency) have been developed for 13 scattered Kansas locations to determine gross irrigation requirement values suitable for sprinklers. Irrigation requirements are given in inches per day and in gallons per minute per acre under continuous application. Gross irrigation requirement values for the July-August period were developed as follows:

Seasonal NIR (from Tables 2.1 and 2.2) x

$$\frac{\text{July + August percent}}{100} \text{ [from Tables 2.3 and 2.4} \div 62 \text{ (for average daily NIR)]} \div \frac{\text{percent delivery efficiency}}{100} \text{ (for average daily GIR)}$$

Similar calculations were done for wheat using the months of April and May.

Both 80 percent chance rainfall and 50 percent chance rainfall considerations are included in the tables. Rainfall at 80 percent chance should be used for good sprinkler irrigation design, but use of the 50 percent chance design is acceptable. It should be recognized that the 50 percent chance design may result in substantially reduced yields in the dryer years.

The data in Tables 5.8, 5.8a, 5.9 and 5.9a for soybeans is adjusted to the period July 15 to September 15 to better fit the irrigation demand period for that crop.

Rainfall normally occurs in one or two events during each of the months of July and August. The monthly allowance for rainfall should not exceed 50 percent of the available water holding capacity of the top 3 feet of the soil profile. Therefore Tables 5.8, 5.8a, 5.9 and 5.9a are generally applicable to soils in irrigation groups 1 through 9. Adjustment is needed for irrigation groups 10, 11 and 12 due to low water holding capacity. Table 5.7 gives the values for this adjustment.

b. <u>Irrigation Application Rate and Soil Intake Rate</u> - A principle of sprinkler irrigation design is that the application rate must not exceed the intake rate of the soil. With center pivot systems, this principle may be difficult to accomplish on 0.1 and 0.3 intake family soils and to some extent on the 0.5 intake family soils, particularly if large irrigation applications are made. Management features that can be used to increase the effective soil intake rate are (1) maintain a ground cover of crop residue during the irrigation period (the heavier the better) up to about 4000 pounds per acre, (2) make light and frequent applications (for example, about 1 inch net application about each 3 1/2 to 4 days) and (3) reduce effective slope by contour operations or leveling. Note that Table 5.2 gives data that takes into account these management features. Tillage may also increase the intake rate.

c. <u>Design Guidelines for High Application Rate Systems</u> - When LEPA and other low pressure nozzles are placed 2 to 3 feet from the soil surface, the application rate of the system exceeds the intake rate of the soil. These systems can still be used if special guidelines are followed.

A concept was developed for using the LEPA nozzles. This LEPA concept as originally developed had each nozzle following a single furrow, used furrow dikes to keep the water from moving and was on field slopes of 1 percent or less.

Research and actual field use has modified the concept. The following criteria should be used when designing a center pivot system using the LEPA concept for low pressure spray nozzles.

The center pivot sprinkler should operate with low pressure, approximately 10 to 25 psi at the pivot point depending on pipe size, amount of water, and field topography. The nozzles will be on drops with outlet spacing not to exceed 10 feet. The nozzles will be 18 to 36 inches above the soil surface when the sprinkler is operating and the lateral is full of water. Pressure at

the nozzles could range from 6 to 20 psi, controlled by pressure regulators that require slightly higher inlet pressure. There should be no end gun.

Tillage operations will need to be incorporated with the system to control runoff. Methods to prevent water movement or runoff include: furrow dikes or pitting, deep chiseling of clay subsoils or plowpans, addition of organic matter, and other tillage practices that leave the soil surface rough and open. Planting in circles or on the contour is recommended.

The slopes of the field should be in the 0 to 3 percent range for the system to work properly. Zero to 1 percent is best--the flatter the slope the better.

High application efficiencies (80 to 95 percent) can be achieved as long as there is no runoff and the water infiltrates before it evaporates. Uniformity can be a problem on sloping fields as the water will move to the low areas.

Net irrigation applications of 1 inch per pass should be used with low pressure systems. Runoff could dramatically increase with higher amounts. Smaller flow rates will also lower application rates. Flow rates for a standard quarter mile system should not exceed 650 gpm with 500 to 550 gpm being more appropriate.

Systems with application rates that exceed the intake rate of the soil must be designed using the LEPA concept, otherwise they must be designed to meet the criteria of conventional systems as stated in 2b page 5-31.

d. <u>Other Center Pivot System Design Considerations</u> - Table 5.11 (Center Pivot Component and Area Relationships), Table 5.12 (Nozzle Discharge and Wetted Diameter for Sprinkler Nozzles), Table 5.12a (Nozzle Discharge and Wetted Diameter for Spray Nozzles) and Table 5.13 (Pressure Loss in Center Pivot Systems) contain information that is usually needed in center pivot design determinations or evaluation assessment.

The following are factual items that generally apply to center pivot design considerations.

(1) Distance of travel for a circular operating system is 6.28 times the system length from the pivot to the outside drive wheel.

(2) The application rate is a function of the wetted diameter of the sprinklers and the system flow rate and is independent of the travel speed.

(3) 100 gpm = .223 acre-inch per hour.

(4) An elliptical water application rate pattern at right angles to the moving lateral is usually assumed. Therefore, the maximum rate of application is approximately 1.27 times the average rate.

e. <u>Center Pivot Sprinkler Design</u> - Use Form KS-ENG-22 (Rev.) This form is used for the design of a center pivot sprinkler system. The following are the steps used in filling out Form KS-ENG-22:

(1) List soils information, land slopes, intake families and design groups. Refer to Part 3 of the Kansas Irrigation Guide for information on irrigated soils. If more than one soil is present with different intake families, design the system for the soil that occurs on the majority of the area. Document if special attention is needed for other areas.

(2) List the crop to be grown and pounds of crop residue per acre at planting time.

(3) Determine the water supply flow rate in gallons per minute (gpm) to be delivered to the system (Q). If at all possible, this should be measured by a flowmeter. If not, the amount could be estimated. One way to estimate the water supply in an existing system is by the following procedure:

(a) Measure the outside circumference of the pipe and divide by 3.1416 to find the diameter of the system pipe.

(b) Take nozzle pressure readings at each end of the system.

(c) Measure the distance between the two nozzles in feet.

(d) Determine the net plus or minus elevation differences in feet between these two nozzles locations.

(e) Knowing the pressure loss from friction from Item (d), refer to Table 5.13 for the estimated gpm in the pipe.

(4) Estimate the center pivot sprinklers wetted radius (R). This is the distance from the pivot point to the point past the end of the center pivot that is receiving adequate water. Also, determine the

distance from the pivot point to the outer drive wheel (r).

(5) Record the wetted diameter of the largest lateral nozzle (w). This can be determined using either Table 5.12 or 5.12a. Also, record the nozzle pressure used in determining the wetted diameter.

(6) Using Table 5.1, estimate the efficiency of the system.

(7) Determine the desired net application per pass of the center pivot sprinkler system (d).

(8) Calculate the gross application per pass (D). Net application divided by efficiency equals gross application.

(9) Record the area irrigated (A) by using the wetted radius. Table 5.11 can be used to calculate this.

(10) Calculate the time to irrigate the area once (T). Take 18.75 times the gross application (D) times the area irrigated (A) and divide by the system flow rate (Q).

(11) Divide system flow rate (Q) by area (A) to obtain gpm/acre.

(12) Find the minimum irrigation requirement, gpm/acre, from the appropriate table, 5.8, 5.8a, 5.9, or 5.9a. The gpm/acre value determined in Item (11) must equal or exceed this figure. If not, either reduce the acres (A) or increase the gpm (Q) to the system.

(13) Using Table 5.2, find the maximum allowable application rate for the intake family, slope, net irrigation and crop residue determined above.

(14) The design application rate is calculated by 192.6 times the distance to outer drive wheel (r) times system flow rate (Q) divided by the product of the wetted radius squared and the wetted diameter of the largest nozzle (w). This is the maximum application rate.

(15) The design application rate shall not exceed the maximum allowable application rate. If it does, then decrease the system flow rate or increase the nozzle wetted diameter as needed.

f. Center Pivot Sprinkler Design Example - Form KS-ENG-22. See Table 5.10a.

Given: Location is Ulysses area. The soil is Ulysses silt loam, (intake family 0.5, design group 5). The crop is corn with a usual residue of 2000 pounds. Land slope is 1.0 percent and water supply (well) is 675 gpm. The wetted radius of the system (R) is 1300 feet and the distance from the pivot to the outer drive wheel (r) is 1250 feet. The wetted diameter (w) of the largest nozzle, 1/4 inch, is 40 feet at 20 psi.

The estimated efficiency is 75 percent and with a desired net application of 1.0 inch the gross application per pass is 1.0 ÷ .75 = 1.33 inches. Area irrigated is 121.9 acres and the time to apply 1.33 inches to 121.9 acres is 18.75 x 1.33 inches x 121.9 acres ÷ 675 gpm = 4.5 days.

The design gpm/acre is 675 gpm ÷ 121.9 acres = 5.5 gpm/acre. This meets the "80 percent chance" gross minimum requirement of 4.7 gpm/acre for corn from Table 5.8.

Maximum allowable application rate, Table 5.2, for 0.5 intake family, 0 to 1 percent slope, 2000 pounds residue, and 1.0 inch net application = 4.2 inches/hour. The design application rate is (192.6 x 1250 feet x 675 gpm) ÷ (1300 feet x 40 feet) = 2.40 inches/hour. The design application rate is less than the maximum allowable. The design is acceptable.

g. Center Pivot Sprinkler System - Field Evaluation - Field evaluation can be done whenever the system is operating. It becomes increasingly difficult when the height of crop increases beyond 3 to 4 feet.

Procedure: Use Form KS-ENG-22a (See Table 5.10b)

(1) Record soil type, design group, land slope, crop and pounds of crop residue per acre. Also, estimate the amount of residue that would have been on the ground at planting.

(2) List the temperature, estimated wind velocity and humidity.

(3) Check the soil moisture conditions in the root zone of the crop using a soil probe or spade. Make estimates of the available moisture and the percentage of field capacity. Note special conditions such as dry zones or compacted layers of soil.

TABLE 5.10a

USDA-SCS

CENTER PIVOT SPRINKLER DESIGN

KS-ENG-22
(Rev. 12/92)

Irrigator Example County Grant

Legal Descr. ______ Plan No. ______

Note: Design data from Part 5 of the Kansas Irrigation Guide.

Soil Ulysses silt loam Intake Family 0.5 Design Group 5

Crop Corn Residue 2000 lbs./ac.; Land Slope 1.0 %

Design Flowrate (Q) 675 gpm; Center Pivot Wetted Radius (R) 1300 ft.

Distance from Pivot to Outer Drive Wheel (r) 1250 ft.

Wetted Diameter of Largest Lateral Nozzle (w) 40 ft.

Nozzle Pressure 20 psi; System Efficiency 75 % (Table 5.1)

Desired Net Application (d) 1.0 in.; Gross Application (D) 1.33 in.

Area Irrigated by Center Pivot Wetted Radius (A) 121.9 ac. (Table 5.11)

Time to Irrigate Entire Area Once (T) = 18.75 x D x A / Q

T = 18.75 x 1.33 x 121.9 / 675 ; T = 4.5 days

Design GPM/Acre: (Q) 675 gpm / (A) 121.9 ac. = 5.5 gpm/ac.

Minimum Gross Irrigation Requirement for Sprinkler 4.7 gpm/ac.
Table 5.8 5.8a, 5.8b, 5.9, 5.9a, or 5.9b (Circle one);
Note: Proposed gpm/ac. must equal or exceed minimum requirements.
If short, reduce acres or increase water supply.

Maximum Allowable Application Rate for specific intake group, slope, net irrigation, and residue = 4.2 in./hr. (Table 5.2)

Design Application Rate = $(192.6 \times r \times Q) / (R^2 \times w)$

Rate = $(192.6 \times 1250 \times 675) / (1300^2 \times 40) = 2.40$ in./hr.

Note: Design application rate must not exceed the maximum allowable rate. Decrease flowrate or increase wetted diameter if needed.

Planned by: ______ Date: ______

Checked by: ______ Date: ______

(4) Note water source and measured Q in g.p.m. into the system. If a flow meter is not available, use the procedure outlined in Item 4c on page 5-23 under Center Pivot Design or Operations Evaluation.

(5) Record the system dimensions and acres irrigated (see Table 5.11).

(6) Set 2 stakes in line with the outer drive wheel, 50 to 100 feet apart. Record the travel time between the 2 stakes in minutes. Travel speed (T.S.) in feet per minute is equal to the distance traveled in feet divided by the time in minutes.

(7) Travel distance in feet for the full circle (T.D.) equals distance from the pivot to the outer drive wheel (D) in feet times 6.28. Travel time, in hours, equals travel distance (T.D.) in feet divided by travel speed (T.S.) in feet per minute times 60. Divide this by 24 to give travel time in days.

(8) Check 2 or more nozzles for excess wear. The size or sizes are stamped on the side of the nozzle. Record the location, nozzle size and the pressure readings taken with a pitot tube and pressure gage. Measure and record the flow from each nozzle in g.p.m. This flow should compare closely with the g.p.m. shown in Tables 5.12 or 5.12a for the pressure and nozzle measured. Observe the water intake, especially near the outer end of the system. Appreciable ponding of water or runoff during and after the system has passed will result in poor efficiency and possible crop damage.

(9) Set gages or cans ahead of the area being irrigated as shown at the top of page 3 of Form KS-ENG-22a. Begin with station 0+00 at the pivot with the first gage or can set at Station 2+00. Set the containers from that point on even spacings of 30-, 40- or 60-foot intervals. Set the gages or cans upright and above the crop canopy. Use 2 heavy rubber bands to secure the gage or can to the stake. For ultra-low pressure systems, gages or cans will not work. Troughs are needed to catch the water that discharges from the nozzles.

(10) After the system has passed over the gages or cans and no more water is entering them, read and measure the amount caught. If cans are used, obtain a graduated cylinder to measure the cubic centimeters (cc) caught. Multiply the cc caught by 0.005 to obtain the water depth in inches. Record this information in the appropriate table on page 2 of Form KS-ENG-22a.

(11) Check the maximum application rate near the end of the system but out of range of the end gun. Use the following procedure and the sketch on page 3 of Form KS-ENG-22a as a guide in measuring the maximum application rate:

(a) Place 5 or 6 stakes evenly spaced 15 to 20 feet apart on a line parallel to the travel direction of the system.

(b) Attach gages or cans to the stakes as nearly as possible at the same time.

(c) Leave the containers on the stakes for 5 to 10 minutes. Use a stop watch.

(d) Remove the gages or cans as nearly as possible at the same time. Record their position in the set.

(e) Measure and record the catch in the table at the bottom of page 3 of Form KS-ENG-22a. The application rate (in./hr.) is equal to the inches caught times 60 divided by the minutes for the set. The gage or can with the greatest depth will give the maximum measured rate.

(12) Computations:

(a) Page 2 - Finish the table and compute weighted average depth in inches as follows:

(i) The depth of water in each gage or can is multiplied by an appropriate factor which is a proportion of the area represented by each gage or can. For example, refer to the sample Form KS-ENG-22a (Table 5.10) on Page 5-41.

Note container No. 1 at Station 2+00 is given a factor of 1. Then the factors are uniformly increased to 2.0 at container No. 9 (Station 4+00). No. 9 represents twice the area as No. 1, then the factors increase to 3.0 at container No. 17 (Station 6+00) which represents 3 times the area as No. 2, and so on. After listing the factors, complete the table by multiplying the factor (F) times the respective inches (I) and then total the factor (F) and I x F columns.

(ii) Divide the sum of I x F's by the sum of the factors (F) to obtain the Weighted Average Depth (in.)

(b) Page 2 - Weighted Low Average Depth - Compute as follows:

(i) This is the average depth over the one-fourth of the field receiving the least water. Divide the sum of factors by 4. This will indicate approximately the sum of factors needed for this representation. Start with the can receiving the least amount of water and proceed to greater depths until as near as possible the one-fourth factor amount is reached.

(ii) Compute the weighted low average depth the same as for the weighted average depth.

(c) Page 3 - Compute the theoretical maximum application rate as follows:

(i) Average application rate (in./hr.) equals the weighted depth (in.) times the travel speed (T.S.) in ft./hr. divided by the wetted diameter in feet.

(ii) The theoretical maximum rate (in./hr.) will be 1.27 times the average application rate. (See Item d4, page 5-33.)

(d) Page 4 -

(i) Finish the computations as shown on the sample Form KS-ENG-22a, Table 5.10b.

(ii) Determine from test data whether the system is operating within acceptable limits.

(iii) Make any needed recommendations or comments as indicated by the field evaluation.

USDA
SCS

KS-ENG-22a
Rev. 8 /84

Page 1 of 4

CENTER PIVOT SPRINKLER FIELD EVALUATION

Owner Example Field Office ____

Legal Descr. ____ Plan No. ____

Soil Richfield silt loam Design Group 3 Land Slope 1 %

Crop Wheat Residue 1000 lbs./ac.

Temperature 80°F Wind 5-10 mph Humidity Low 15-20 %

Soil Moisture 50 % of Field Capacity

Water Supply Well Measured Q 770 g.p.m.

Type of System Gifford Hill with 360° spray nozzles

Operation Data: End Gun - (Not Used)(Corners)(Continuous)

Remarks ____

System Dimensions

Distance, Pivot to Tower No. 1 125.5 ft., Tower Spacing 124 ft.

End Tower to End 35 ft., Total System Length 1277 ft.

Distance, D to Outer Drive Wheel 1242 ft.

Acres Irrigated 120 (Table 5.6 - Kansas Irrig. Guide).

Travel Speed, T.S., (100 ÷ Travel Time, minutes) 100 ÷ 51.9 = 1.93 ft./min.

Travel Distance, T.D. = 6.28 x D 1242 ft. = 7804 ft.

Travel Time = T.D. ÷ (T.S. x 60) = 7804 ÷ (1.93 x 60) = 67.4 hrs.
2.81 days

Nozzle Data

Location	Nozzle Size	Pressure, p.s.i.	Measured g.p.m.	Table 5.7 g.p.m.
6+40	3/16"	19	5	4.45
9+80	9/32"	15	9	8.65
12+05	9/32"	15	8	8.65

CONTAINER DATA

Sta.	Can No.	C.C.*	Inches I.	Factor F.	I. x F.
2+00	1		0.90	1.0	0.90
2+25	2		0.85	1.125	0.956
2+50	3		0.80	1.25	1.00
2+75	4		0.60	1.375	0.825
3+00	5		0.70	1.5	1.05
3+25	6		0.85	1.625	1.381
3+50	7		1.30	1.75	2.275
3+75	8		0.90	1.875	1.688
4+00	9		0.80	2.0	1.60
4+25	10		0.90	2.125	1.913
4+50	11		1.00	2.25	2.25
4+75	12		0.90	2.375	2.138
5+00	13		0.80	2.5	2.00
5+25	14		1.00	2.625	2.625
5+50	15		0.95	2.75	2.613
5+75	16		0.90	2.875	2.588
6+00	17		0.75	3.0	2.25
6+25	18		0.95	3.125	2.969
6+50	19		0.90	3.25	2.925
6+75	20		1.00	3.375	3.375
7+00	21		0.80	3.5	2.80
7+25	22		0.75	3.625	2.719
7+50	23		0.55	3.75	2.063
7+75	24		0.55	3.875	2.131
8+00	25		0.90	4.0	3.60
8+25	26		0.70	4.125	2.888
8+50	27		0.80	4.25	3.40
8+75	28		0.80	4.375	3.50
9+00	29		0.95	4.5	4.275
9+25	30		0.95	4.625	4.394
9+50	31		0.60	4.75	2.85
9+75	32		1.10	4.875	5.363
10+00	33		0.90	5.0	4.50
10+25	34		0.80	5.125	4.10
10+50	35		0.90	5.25	4.725
10+75	36		0.95	5.375	5.106
11+00	37		0.70	5.5	3.85
11+25	38		0.90	5.625	5.063
11+50	39		0.95	5.75	5.463
11+75	40		1.10	5.875	6.463
12+00	41		0.85	6.0	5.10
12+25	42		0.95	6.125	5.819
12+50	43		0.95	6.25	5.934
12+75	44		0.55	6.375	3.506
13+00	45		—	6.5	—
			Sum	162.25	138.933

*c.c. x 0.005 = inches

Container spacing 25 ft.

Pivot to Container No. 1 200 ft.

Hr./Rev. 67.4 hr.

Weighted Ave. Depth:

$$\frac{\text{Sum } I \times F}{\text{Sum } F} = \frac{138.933}{162.25}$$

$$= 0.86 \text{ in.}$$

Weighted Low Ave. Depth:

Sum F for 1/4 Area

$$\frac{\text{Sum } F}{4} = \frac{162.25}{4} = 40.56$$

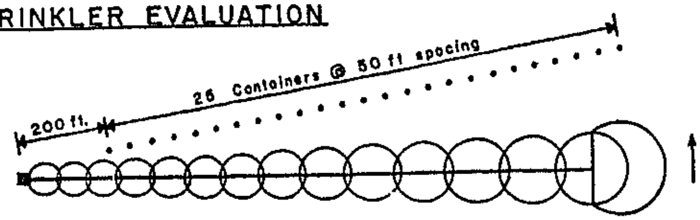
Can No.	Inches I_1	Factor F_1	$I_1 \times F_1$
23	0.55	3.75	2.063
24	0.55	3.875	2.131
44	0.55	6.375	3.506
4	0.60	1.375	0.825
31	0.60	4.75	2.85
5	0.70	1.50	1.05
26	0.70	4.125	2.888
37	0.70	5.5	3.85
17	0.75	3.0	2.25
22	0.75	3.625	2.719
13	0.80	2.5	2.00
	Sum	40.375	26.132

$$\frac{\text{Sum } I_1 \times F_1}{\text{Sum } F_1} = \frac{26.132}{40.375}$$

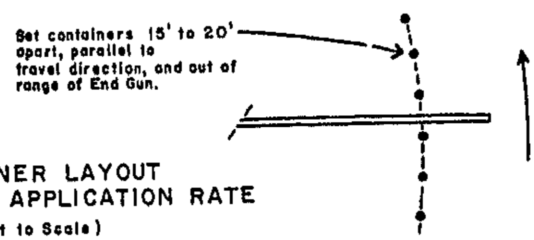
$$= 0.65 \text{ in.}$$

(Continue Computations on Page 4)

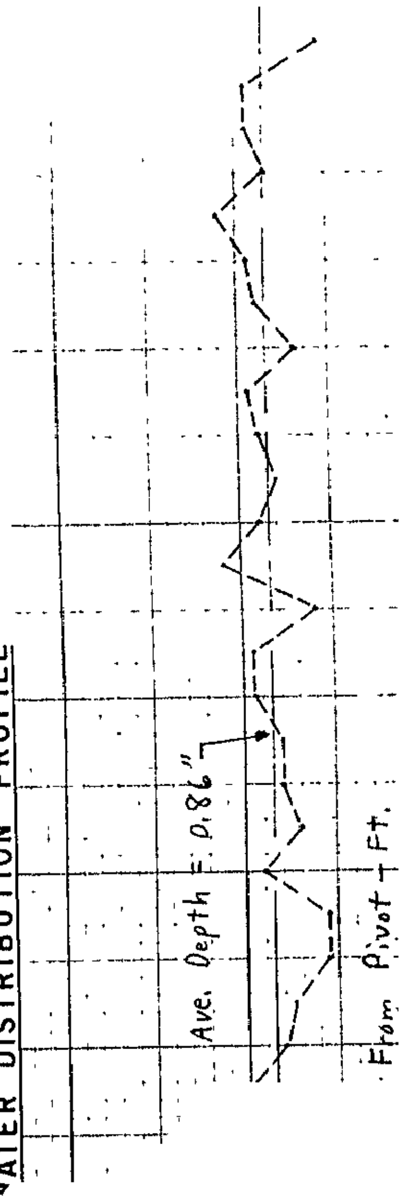
C-P SPRINKLER EVALUATION



SETUP FOR TYPICAL EVALUATION



CONTAINER LAYOUT
FOR MAXIMUM APPLICATION RATE
(Not to Scale)



WATER DISTRIBUTION PROFILE

MAXIMUM APPLICATION RATE

Location, Sta. 12+00 Can Spacing 15 ft.

Can No.	Cubic Centi.	Inches	In./Hr.
1		.00	0.00
2		.10	0.40
3		.48	1.92
4		.58	2.32
5		.10	0.40
6		.00	0.00

Set Time 15 min., Max. Applic. .5

Rate = $\frac{\text{Inches Caught}}{\text{Minutes Set}}$ X 60 = $\frac{.58}{15}$ X 60 = 2.3

THEORETICAL MAXIMUM APPLICATI

Ave. Depth = .86 in.; Travel Speed, T.S. =
(From page 2)

Wetted Diameter, W.D. = 40 ft. (from t

Ave. Applic. Rate = $\frac{\text{Ave. Depth X T.S.}}{\text{W.D.}}$ = $\frac{.86 \times 115.8}{40}$

Max. Applic. Rate = 1.5 X Ave. Rate = 1.5 X 2.49

COMPUTATIONS AND SUMMARY

Name Example

Date

From Page 2:

Pattern Efficiency:

$$\frac{\text{Weighted Low Ave. Depth (in.)} \times 100}{\text{Weighted Ave. Depth (in.)}} = \frac{.65 \times 100}{.85} = 76.5\ \%$$

Gross Depth Pumped:

$$\frac{\text{(G.P.M.)(Hr./Rev.)}}{450 \times \text{Acres}} = \frac{(770)(67.4)}{450 \times 120} = 0.96\ \text{in.}$$

Application Efficiency:

$$\frac{\text{Weighted Ave. Depth (in.)} \times 100}{\text{Gross Depth Pumped (in.)}} = \frac{.86 \times 100}{.96} = 89.6\ \%$$

System Efficiency:

$$\frac{\text{Application Eff. (\%)} \times \text{Pattern Eff. (\%)}}{100} = 76.5 \times 89.6 = 68.5\ \%$$

Maximum Allowable Application Rate (Table 5.2 OR 5.2a) = 2.55 in./hr.

Maximum Application Rate (Page 3), Measured = 2.32 in./hr.

Computed = 3.74 in./hr.

System is or is not operating within Acceptable Limits (circle one).

Comments or Recommendations: Soil profile should be filled to field capacity early in the season. Check nozzles at stations 3+50, 7+25 to 7+75, 9+50 to 9+75, and 12+75.

System Evaluation By Example

Title

Date

TABLE 5.11

Center Pivot Component and Area Relationships

Total System Length (in feet) 1/	% of Water Applied in Last 100 ft. 2/	Area Covered in Acres 3/ Without Using End Gun	With End Gun Used Only in Corners	With End Gun Used on Entire Circle
500	36.0	18.0	22.0	26.0
550	33.1	21.8	26.2	30.5
600	30.6	26.0	30.8	35.3
650	28.4	30.5	36.0	40.6
700	26.5	35.3	41.3	46.2
750	24.8	40.6	47.2	52.1
800	23.4	46.2	53.3	58.4
850	22.1	52.1	59.8	65.1
900	21.0	58.1	66.7	72.2
950	20.0	65.1	74.0	79.5
1000	19.0	72.1	81.7	87.3
1050	18.1	79.5	89.5	95.4
1100	17.4	87.3	98.0	103.9
1150	16.6	95.3	106.6	112.7
1200	16.0	103.9	115.7	121.9
1250	15.4	112.7	123.8	131.4
1300	14.8	121.9	134.0	141.4
1350	14.3	131.4	145.0	151.6
1400	13.8	141.4	155.2	162.3
1450	13.3	151.6	166.5	173.3
1500	12.9	162.3	177.7	184.6

1/ Generally last tower approximately 50 feet from end
2/ Less volume of end gun when used
3/ Based on 100 foot gun coverage

Example: System is 1300 feet long. Then 14.8 percent of water is applied in last 100 feet. 121.9 acres are covered without using end gun.

TABLE 5.12

Nozzle Discharge and Wetted Diameter for Sprinkler Nozzles

Nozzle Size (Inches)		Nozzle Pressure (pounds per square inch)										
		25	30	35	40	45	50	55	60	65	70	75
3/32	Flow (gpm)	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0			
	Dia. (feet)	61	63	64	66	67	68	69	70			
7/64	Flow (gpm)	1.7	1.9	2.0	2.2	2.3	2.4	2.6	2.7			
	Dia. (feet)	67	69	70	71	72	74	75	77			
1/8	Flow (gpm)	2.2	2.4	2.6	2.8	3.0	3.2	3.3	3.5	3.6		
	Dia. (feet)	72	74	76	78	79	81	82	84	85		
9/64	Flow (gpm)	2.9	3.2	4.3	3.6	3.8	4.0	4.2	4.4	4.6		
	Dia. (feet)	78	80	81	83	85	86	88	90	92		
5/32	Flow (gpm)	3.5	3.9	4.2	4.5	4.7	5.0	5.2	5.5	5.7	5.9	
	Dia. (feet)	84	86	88	90	91	93	95	96	98	99	
11/64	Flow (gpm)	4.3	4.7	5.1	5.4	5.7	6.0	6.3	6.6	6.8	7.1	
	Dia. (feet)	90	92	94	96	98	100	102	103	105	106	
3/16	Flow (gpm)	5.0	5.5	6.0	6.4	6.8	7.2	7.5	7.8	8.1	8.4	8.7
	Dia. (feet)	95	97	100	102	104	106	108	110	111	113	114
13/64	Flow (gpm)	5.9	6.5	7.1	7.6	8.1	8.5	8.9	9.2	9.5	9.8	10.2
	Dia. (feet)	100	103	106	108	111	112	114	116	118	120	122
7/32	Flow (gpm)	6.8	7.6	8.3	8.9	9.4	9.9	10.3	10.7	11.2	11.6	12.0
	Dia. (feet)	106	109	111	113	115	117	119	121	123	125	126
1/4	Flow (gpm)		9.9	10.7	11.4	12.1	12.8	13.5	14.1	14.8	15.4	16.0
	Dia. (feet)		113	116	119	122	125	128	131	133	136	139
9/32	Flow (gpm)		12.4	13.4	14.3	15.2	16.1	17.0	17.9	18.7	19.5	20.3
	Dia. (feet)		118	122	125	129	132	135	139	141	144	146
5/16	Flow (gpm)		15.2	16.5	17.7	18.9	20.0	21.0	22.0	23.0	23.9	24.8
	Dia. (feet)		124	128	132	135	139	143	146	149	152	154
11/32	Flow (gpm)			19.7	21.1	22.4	23.6	24.8	25.9	27.0	28.1	29.2
	Dia. (feet)			133	139	143	146	150	153	156	159	161
3/8	Flow (gpm)			22.8	24.4	26.0	27.6	29.2	30.6	32.0	33.3	34.5
	Dia. (feet)			140	145	149	154	157	160	163	165	168
13/32	Flow (gpm)			27.2	29.1	30.9	32.7	34.3	35.9	37.4	38.9	40.3
	Dia. (feet)			147	152	156	159	163	166	169	172	174
7/16	Flow (gpm)				33.9	35.9	37.8	39.7	41.5	43.3	45.1	46.8
	Dia. (feet)				158	162	165	169	172	175	179	181
15/32	Flow (gpm)				38.9	41.1	43.3	45.4	47.4	49.4	51.4	58.3
	Dia. (feet)				163	167	172	175	179	182	184	187
1/2	Flow (gpm)				43.6	46.0	48.4	50.7	53.0	55.3	57.5	59.6
	Dia. (feet)				169	174	178	182	184	188	191	193
17/32	Flow (gpm)					51.6	54.0	56.4	58.8	61.2	63.5	65.8
	Dia. (feet)					179	184	188	192	194	196	199
9/16	Flow (gpm)					57.5	60.6	63.6	66.5	69.4	72.2	74.9
	Dia. (feet)					185	189	193	196	199	202	204
5/8	Flow (gpm)					70.0	73.6	77.2	80.8	84.4	87.8	91.0
	Dia. (feet)					190	194	198	201	204	207	211

TABLE 5.12a

Nozzle Discharge and Wetted Diameter for Spray Nozzles

	Sprinkler Base Pressure (psi)					
	6	10	15	20	25	30
#5 Nozzle – Beige (5/64")						
Flow (gpm)	0.43	0.55	0.66	0.76	0.87	0.97
Diam. at 6' Ht. (ft)	13.0	15.6	16.5	18.0	19.5	21.0
Diam. at 9' Ht. (ft)	17.0	19.0	20.5	22.0	23.3	24.5
Diam. at 12' Ht. (ft)	21.0	23.0	24.5	26.0	27.0	28.0
#6 Nozzle – Gold (3/32")						
Flow (gpm)	0.64	0.82	0.98	1.14	1.27	1.40
Diam. at 6' Ht. (ft)	16.8	18.7	20.0	21.3	22.5	23.8
Diam. at 9' Ht. (ft)	19.7	22.0	23.9	25.8	26.9	28.1
Diam. at 12' Ht. (ft)	22.6	25.3	27.8	30.3	31.5	32.3
#7 Nozzle – Lime (7/64")						
Flow (gpm)	0.87	1.12	1.34	1.56	1.73	1.90
Diam. at 6' Ht. (ft)	20.0	22.3	23.5	24.7	25.7	26.7
Diam. at 9' Ht. (ft)	22.1	24.8	27.3	29.7	30.7	31.7
Diam. at 12' Ht. (ft)	24.3	27.6	31.1	34.7	35.7	36.7
#8 Nozzle – Lavender (1/8")						
Flow (gpm)	1.12	1.45	1.73	2.01	2.23	2.45
Diam. at 6' Ht. (ft)	24.5	26.0	27.0	28.0	28.7	29.5
Diam. at 9' Ht. (ft)	[illegible]	28.0	30.7	33.5	34.4	35.3
Diam. at 12' Ht. (ft)	[illegible]	30.0	31.5	33.0	[illegible]	41.0
#9 Nozzle – Gray (9/64")						
Flow (gpm)	1.41	1.82	2.17	2.52	2.79	3.06
Diam. at 6' Ht. (ft)	25.3	27.5	28.2	29.5	30.3	31.2
Diam. at 9' Ht. (ft)	26.5	29.1	31.0	31.7	35.7	36.8
Diam. at 12' Ht. (ft)	27.3	31.3	35.6	40.0	41.0	42.0
#10 Nozzle – Turquoise (5/32")						
Flow (gpm)	1.74	2.25	2.69	3.12	3.47	3.81
Diam. at 6' Ht. (ft)	26.8	28.0	29.5	31.0	32.0	33.0
Diam. at 9' Ht. (ft)	27.6	30.3	33.1	36.5	37.0	38.0
Diam. at 12' Ht. (ft)	28.7	32.8	36.8	41.0	42.0	43.0
#11 Nozzle – Yellow (11/64")						
Flow (gpm)	2.05	2.65	3.21	3.76	4.17	4.57
Diam. at 6' Ht. (ft)	[illegible]	28.5	30.1	31.7	33.1	34.5
Diam. at 9' Ht. (ft)	28.8	[illegible]	34.0	36.8	38.1	39.5
Diam. at 12' Ht. (ft)	[illegible]	31.0	32.0	41.8	43.0	44.0
#12 Nozzle – Red (3/16")						
Flow (gpm)	2.45	3.16	3.81	4.45	4.96	5.47
Diam. at 6' Ht. (ft)	27.5	29.0	30.7	32.5	34.2	36.0
Diam. at 9' Ht. (ft)	[illegible]	31.7	31.5	37.4	38.9	40.4
Diam. at 12' Ht. (ft)	[illegible]	34.5	38.4	42.2	43.5	44.7
#13 Nozzle – White (13/64")						
Flow (gpm)	2.92	3.77	4.50	5.23	5.84	6.44
Diam. at 6' Ht. (ft)	27.9	29.2	31.2	33.2	31.8	36.5
Diam. at 9' Ht. (ft)	[illegible]	32.1	35.0	37.9	39.4	40.9
Diam. at 12' Ht. (ft)	[illegible]	33.0	38.8	42.6	44.0	45.3
#14 Nozzle – Blue (7/32")						
Flow (gpm)	3.40	4.39	5.24	6.09	6.82	7.54
Diam. at 6' Ht. (ft)	28.3	29.5	31.7	34.0	35.5	37.0
Diam. at 9' Ht. (ft)	30.2	32.5	35.4	38.4	40.0	41.5
Diam. at 12' Ht. (ft)	31.8	35.5	39.2	43.0	44.5	46.0
#15 Nozzle – Dark Brown (15/64")						
Flow (gpm)	3.91	5.05	6.03	7.00	7.82	8.64
Diam. at 6' Ht. (ft)	28.7	29.7	32.1	34.5	36.0	37.5
Diam. at 9' Ht. (ft)	30.5	32.5	35.8	38.9	40.5	42.1
Diam. at 12' Ht. (ft)	32.3	36.0	39.6	43.3	45.0	46.7

	Sprinkler Base Pressure (psi)					
	6	10	15	20	25	30
#16 Nozzle – Orange (1/4")						
Flow (gpm)	4.48	5.79	6.91	8.03	8.93	9.82
Diam. at 6' Ht. (ft)	29.0	30.0	32.5	35.0	36.5	38.0
Diam. at 9' Ht. (ft)	30.9	33.2	36.2	39.3	41.0	42.7
Diam. at 12' Ht. (ft)	32.0	35.5	40.0	43.6	45.5	47.3
#17 Nozzle – Dark Green (17/64")						
Flow (gpm)	5.03	6.50	7.76	9.01	10.02	11.03
Diam. at 6' Ht. (ft)	29.3	30.2	32.8	35.5	36.9	38.3
Diam. at 9' Ht. (ft)	31.4	33.6	36.6	39.7	41.5	43.2
Diam. at 12' Ht. (ft)	33.5	37.0	[illegible]	44.0	46.0	46.0
#18 Nozzle – Purple (9/32")						
Flow (gpm)	5.62	7.25	8.65	10.04	11.15	12.25
Diam. at 6' Ht. (ft)	29.6	[illegible]	33.2	36.0	37.3	38.6
Diam. at 9' Ht. (ft)	31.6	33.5	36.0	40.1	[illegible]	43.6
Diam. at 12' Ht. (ft)	33.7	37.2	40.7	44.2	46.4	48.6
#19 Nozzle – Black (19/64")						
Flow (gpm)	6.19	7.99	9.54	11.08	12.32	13.55
Diam. at 6' Ht. (ft)	29.9	30.7	33.6	36.5	37.7	38.9
Diam. at 9' Ht. (ft)	31.6	34	37.2	40.5	42.3	[illegible]
Diam. at 12' Ht. (ft)	35.9	37.4	[illegible]	44.5	46.9	49.3
#20 Nozzle – Dark Turquoise (5/16")						
Flow (gpm)	6.78	8.75	10.44	12.13	13.56	14.99
Diam. at 6' Ht. (ft)	30.2	[illegible]	[illegible]	[illegible]	[illegible]	39.2
Diam. at 9' Ht. (ft)	[illegible]	34.3	37.6	40.9	42.6	44.3
Diam. at 12' Ht. (ft)	[illegible]	37.6	41.2	44.8	47.4	49.9
#21 Nozzle – Mustard (21/64")						
Flow (gpm)	7.37	9.52	11.36	13.20	14.81	16.41
Diam. at 6' Ht. (ft)	30.4	31.2	34.3	37.5	38.5	39.5
Diam. at 9' Ht. (ft)	32.5	34.5	37.8	41.3	43.2	45.1
Diam. at 12' Ht. (ft)	31.2	37.6	41.4	45.1	47.9	50.6
#22 Nozzle – Maroon (11/32")						
Flow (gpm)	7.97	10.29	12.28	14.27	16.09	17.90
Diam. at 6' Ht. (ft)	30.6	31.5	34.7	38.0	38.9	39.8
Diam. at 9' Ht. (ft)	32.4	34.7	38.2	41.7	43.6	45.1
Diam. at 12' Ht. (ft)	34.5	38.0	41.7	45.4	48.3	51.2
#23 Nozzle – Cream (23/64")						
Flow (gpm)	8.86	11.18	13.34	15.50	17.50	19.49
Diam. at 6' Ht. (ft)	30.8	31.7	35.1	38.5	39.3	40.4
Diam. at 9' Ht. (ft)	32.6	34.0	36.5	41.7	44.5	46.5
Diam. at 12' Ht. (ft)	34.4	38.2	41.9	45.7	48.8	51.9
#24 Nozzle – Dark Blue (3/8")						
Flow (gpm)	9.34	12.06	14.40	16.73	18.88	21.03
Diam. at 6' Ht. (ft)	31.0	32.0	35.5	39.0	39.7	40.4
Diam. at 9' Ht. (ft)	32.7	35.1	36.8	42.5	44.5	46.5
Diam. at 12' Ht. (ft)	34.4	38.4	42.2	46.0	49.3	52.5
#25 Nozzle – Copper (25/64")						
Flow (gpm)	10.10	13.04	15.56	18.08	20.35	22.61
Diam. at 6' Ht. (ft)	31.2	32.2	35.8	39.5	40.1	40.7
Diam. at 9' Ht. (ft)	32.9	35.3	39.0	42.8	44.8	46.8
Diam. at 12' Ht. (ft)	34.6	38.5	42.3	46.2	49.5	52.8
#26 Nozzle – Bronze (13/32")						
Flow (gpm)	10.92	14.10	16.83	19.56	21.88	24.20
Diam. at 6' Ht. (ft)	31.4	32.5	36.2	40.0	40.5	41.0
Diam. at 9' Ht. (ft)	33.0	35.5	39.3	43.1	45.1	47.0
Diam. at 12' Ht. (ft)	34.7	38.6	42.4	46.3	49.7	53.0

1/ Senninger Performance Data

2/ Using flat medium-grooved deflector pad with no wind

3/ At 12' height – for concave pad subtract 5' from above diameters
At 9' height – for concave pad add 5', for convex pad subtract 5' from above diameters
At 6' height – for concave pad add 5', for convex pad subtract 5' from above diameters

4/ For 180 spray nozzle use 1/2 of diameter from above for same nozzle size and pressure

5/ For wobbler pad add 10' to the above diameters

TABLE 5.13

Pressure Loss in Center Pivot System (psi)

System Length Feet	Pipe Size Inches	Flowrate at Pivot Point 300 gpm	400 gpm	500 gpm	600 gpm	700 gpm	800 gpm	900 gpm	1000 gpm	1100 gpm	1200 gpm
600	4	11	18	27							
	5	3.5	6	9							
700	5	4	7	11	15						
	6	1.7	3	4.5	6						
800	5	4.5	8	12	18	24					
	6	2	3.5	5	7	10					
	5	5	9	14	20	27	34				
900	6	2.3	4	6	8	11	14				
	6.5					7	10				
	5	5.5	10	16	23	30	38				
1000	6	2.6	4.5	6.5	9	12	15	19			
	6.5					8	11	14			
	5	6	11	17	25	33	42				
1100	6	3	5	7	10	13	17	21	26		
	6.5				6	9	12	15	18		
	5		12	19	27	36					
1200	6		5.5	7.5	11	15	19	23	28	35	
	6.5		3.5	5	7	10	13	16	19	23	
	6			8	12	16	20	25	31	37	45
1300	6.5			5.5	8	11	14	17	21	25	30
	7				5	7	9	12	15	18	22
	6				13	17	22	27	33	40	48
1400	6.5				9	12	15	19	23	27	32
	7				6	8	10	13	16	19	23
	6					18	23	29	35	42	51
1500	6.5					13	16	20	24	28	34
	7					9	11	14	17	20	24
	6						25	31	37	45	54
1600	6.5						17	21	26	30	36
	7						12	15	18	21	25
	6							33	39	47	57
1700	6.5							23	27	32	38
	7							16	19	22	26
	6								41	50	60
1800	6.5								29	34	40
	7								20	23	27

3. <u>Continuous Move Volume Gun System (Traveling Gun)</u> - A typical continuous move volume gun system (traveling sprinkler system) consists of the following major components: pumping plant, mainline, flexible hose, traveler unit and gun sprinkler. Pumping plants and mainline were discussed under Periodic-Move Sprinkler Systems. More detailed information on traveling sprinklers can be found in the National Engineering Handbook, Section 15, Chapter 11 - Sprinkle Irrigation.

   a. <u>Sprinkler Selection</u> - Sprinkler characteristics that need to be considered are nozzle size and type, operating pressure, jet trajectory and sprinkler body design. The operating conditions that enter into the selection process are soil infiltration characteristics; desired depth and frequency of irrigation; towpath length, potential towpath spacings and number of paths for each potential spacing; wind conditions; crop characteristics and the mechanical properties of the soil.

      Gun sprinklers used in most travelers have trajectory angles ranging between 18^{o} and 32^{o}. For average conditions, trajectories between 23^{o} and 25^{o} are satisfactory. This range gives reasonable uniformity in moderate winds, has gentle enough drop impact for most crops and soils and is suitable for operation on varying slopes. Most gun sprinklers can be fitted with either tapered or orifice-ring nozzles. Tapered nozzles have a greater distance of throw, and the ring nozzles have smaller droplet size for the same discharge and pressure.

      Typical nozzle discharges and diameters of coverage are presented in Table 5.14 for gun sprinklers with 24^{o} angles of trajectory and tapered nozzles. The wetted diameter would increase or decrease about 1 percent for each 1^{o} change in trajectory angle. Ring nozzles sized to give the same pressures would produce diameters that are about 5 percent smaller than those presented in the table.

      Both full-circle and part-circle gun sprinklers are available in all nozzle types and size ranges. Some sprinklers need to be operated with part-circle coverage to give even water distribution, a dry path or both. The use of part-circle sprinklers increases the application rate.

The actual application rate at which water must infiltrate into the soil to eliminate runoff is approximately given by this equation:

$$I = \frac{96.3\ q}{pi(0.45w)^2} \times \frac{360}{w^o}$$

Where: I = approximate actual application rate (iph)
q = sprinkler discharge (gpm)
pi = 3.1415...
w_o = wetted diameter (ft)
w^o = portion of circle receiving water (degrees)

The traveler selected should provide the required flow rate and power to drag the hose at the travel speeds necessary to meet the design criteria. Controls to provide a uniform speed of travel that will not vary more than ±10 percent as the traveler moves from one end of the field to the other and positive shutoff at the end of travel are essential.

b. Towpath Spacing - Tests have shown that application uniformity is considerably affected by wind velocity and direction, quantity of water output, jet trajectory, type of nozzle and operating pressure. The tests have also shown that a towpath spacing of 80 percent of the wetted diameter would produce excellent uniformity under very calm wind conditions, whereas closer spacings would produce excessive application midway between adjacent towpaths.

Table 5.15 gives recommended towpath spacing for 23^o to 25^o trajectory sprinklers as a function of wetted diameter and anticipate average wind velocities. These towpath spacings will ensure full coverage midway between towpaths. The higher percentage values should be used for tapered nozzles and the lower values for ring nozzles.

c. Travel Speed - The travel speed should be set to traverse the length of the towpath so that there will be little down time and either 1 or 2 setups per day. For a 1320-foot run with 2 sets and 1 hour to move the traveler to the next towpath and set up, the travel speed would be approximately 2 ft./min. One set per day should have a travel speed of 0.9 to 1.0 ft./min. In some cases the traveler has to be stationary at each end of the run to allow the full irrigation to be applied to the entire field.

d. Application Depth - The rate of application is unaffected by travel speed, but the depth of application is a function of speed. The average depth of water applied per irrigation by a traveling sprinkler can be computed by :

$$d = \frac{1.605\ q}{W\ S}$$

Where: d = gross depth of application (in)
q = sprinkler discharge (gpm)
W = towpath spacing (ft)
S = travel speed (ft/min)

e. Friction Losses in Hose and Traveler - To calculate the pressure required at the pump to operate the sprinkler, the friction losses in the hose and through the traveler should be determined. These losses are then added to the sprinkler pressure to determine the total pressure needed. More information on hose and traveler friction losses can be found in the National Engineering Handbook, Section 15, Chapter 11 - Sprinkle Irrigation.

f. Design Example

Given: The field is 1/2 mile long and 1/4 mile wide with a well in the middle of the long side. The traveler has a sprinkler with a 1.4-inch nozzle which will discharge 500 gpm at 80 psi. The traveler will water 270° of the circle. Net irrigation requirement is 1.5 inches per pass.

From Table 5.14 the wetted diameter is 450 feet. Using the equation for calculating application rate for travelers with q = 500 gpm, w = 450 feet and w° = 270° the rate is 0.50 iph. From Table 5.15 for 450 feet of wetted diameter and 75 percent coverage, the towpath spacing is 338 feet. For the field this would equate to 8 towpaths of 325 feet each. The traveler will take a full day for each towpath. Travel speed is 1300 feet divided by 23 hours (1 hour to move traveler) for a rate of .94 ft/min.

Application depth for q = 500 gpm, W = 325 feet, and S = .94 ft/min is 2.63 inches. At an efficiency of 70 percent, the net application is 1.84 inches. It will require 8 days to irrigate the entire field and the average water applied per day would be .23 inch on the entire field

and rate and drift losses. Assuming that the application pattern under the sprinklers is elliptical, the average application rate is calculated using the equation from the periodic move section; and the average application rate is calculated using:

$$I = \frac{96.3\ Q}{L\ w}$$

Where: I = the average application rate (iph)
Q = system discharge (gpm)
L = length of lateral (ft)
w = wetted width of water pattern (ft)

b. <u>Application Depth</u> - The depth of water applied is a function of the application rate and lateral travel speed; however, lateral travel speed does not affect the application rate which is controlled by sprinkler nozzle size and operating pressure. If the application decreases for any reason, the speed of lateral movement will likewise need to be reduced to apply the same total depth of water. This means there will be a decrease in acreage that can be irrigated by the system in a given period.

c. <u>Example</u>

Given: Field is 1300 feet by 2600 feet with Eudora silt loam soil on 0 to 1 percent slopes. The crop is corn with 1000 pounds of residue per acre at planting. The application depth is 2.0 inches net per irrigation. A well supplies 750 gpm to a linear move system that is 1300 feet long. Sprinkler nozzles on the system have a wetted diameter of 37 feet at 18 psi. Find the average application rate of the system and the time required to irrigate the entire field.

From the average application rate equation I = (96.3 x 750 gpm) ÷ (1300 feet x 37 feet). I = 1.50 inches per hour. From Table 5.2 for a 1.0 inch intake soil, 0 to 1 percent slope, 2-inch net irrigation and 1000 pounds residue the maximum application rate is 2.7 inches per hour. The application rate of the system meets the design requirements.

The area of the field is (1300 x 2600) ÷ 43560 = 77.6 acres. Gross water applied per irrigation is 2 inches ÷ 75 percent efficiency = 2.67 inches. Water used is 750 gpm ÷ 450 = 1.67 acre-inches per hour. Time to irrigate the field is (2.67 inches x 77.6 acres) ÷ (1.67 acre-inches per hour) = 124 hours or 5.2 days. Travel speed is 2600 feet ÷ (124 x 60 minutes) = .35 foot/minute.

TABLE 5.14

Typical Discharges and Wetted Diameters for Gun Sprinklers with 24 Degree Angles of Trajectory and Tapered Nozzles Operating When There Is No Wind

	Tapered Nozzle Size (in)									
	0.8		1.0		1.2		1.4		1.6	
Sprinkler Pressure	Sprinkler Discharge and Wetted Diameter									
psi	gpm	ft	gpm	ft	gpm	ft	gpm	ft	gpm	ft
60	143	285	225	325	330	365	–	–	–	–
70	155	300	245	340	355	380	480	435	–	–
80	165	310	260	355	380	395	515	455	675	480
90	175	320	275	365	405	410	545	470	715	495
100	185	330	290	375	425	420	575	480	755	510
110	195	340	305	385	445	430	605	490	790	520
120	205	350	320	395	465	440	630	500	825	535

TABLE 5.15

Recommended Towpath Spacings for Traveling Sprinklers

Sprinkler Wetted Diameter	Percent of Wetted Diameter						
	50	55	60	65	70	75	80
	Wind over 10 mph		Wind up to 10 mph		Wind up to 5 mph		No Wind
ft	ft	ft	ft	ft	ft	ft	ft
200	100	110	120	130	140	150	160
250	125	137	150	162	175	187	200
300	150	165	180	195	210	225	240
350	175	192	210	227	245	262	280
400	200	220	240	260	280	300	320
450	225	248	270	292	315	338	360
500	250	275	300	325	350	375	400
550	275	302	330	358	385	412	440
600	300	330	360	390	420	–	–

Use the lower percent numbers for ring nozzles and the higher percent numbers for tapered nozzles for the three wind speeds.

PART 5A - TRICKLE IRRIGATION

A. General Information

Trickle irrigation can be defined as the precise application of measured amounts of water at low pressure through a network of small diameter pipes to mechanical outlets. These outlets apply the water directly to or at the root zone of the plant. The principle objective is to obtain optimum plant growth by supplying sufficient moisture to meet the evapotranspiration needs while using a minimum amount of water.

B. System Components (see figure 5A-1)

1. Water Source

Surface or well water can be used. The main concern is water quality, that is, to be sure the water does not contain harmful concentrations of salts and other undesirable mineral elements. The filtering system must also provide clean enough water to prevent clogging of the system components

2. Regulators

These should be installed at the hydrant or at other locations in the system as needed to provide the correct operating pressure. For example, most farmstead water systems operate between 30 to 60 psi, while most drip systems operate best between 20 to 30 psi of initial pressure.

3. Pressure Gages

It is best to use two gages at the water source. They should be located:

a. Following the hydrant (or regulator if used) or inflow point of the system. Its reading will indicate whether there is proper inflow pressure.

b. Following the filter (see item 5 below). This gage will show when and if the filter is clogged or partially blocked and needs cleaning or replacement.

4. Injection System

Install ahead of the filter. Injectors are used to inject fertilizer or other chemicals into the system. Cleaning agents such as chlorine for algae buildup and HCL acid for bicarbonate clogging can be introduced through the injector.

If an injector is not installed during the initial installation, a tap or other fixture(s) should be installed to provide easy access if injection is needed at a later date. A check valve should be considered if there is any possibility of backflow into a domestic water system. Loss of pressure could result in backflow of fertilizer or other chemicals.

5. Filters

A filter should be used on most systems regardless of water source. An in-line filter is usually sufficient for well water. The filter opening should not exceed one-fourth the diameter of the emitter opening. Usually a 100-mesh filter is adequate for most systems.

If surface water (pond, river, etc.) is used, it may be necessary to use a sand screen, and/or sand separators. These may be needed in single or combination units to remove sand, algae, trash, etc.

Filters are cleaned manually or may be automated.

6. Main Line

This line carries the main flow away from the water source. It is usually PVC pipe, 3/4 to 1½ inches in diameter, and is normally buried. Usual depth is from 24 to 30 inches or below frost line. Polyethylene (PE) pipe may also be used.

7. Manifold or Sub-mains

This is an extension of the main line where the lateral lines branch off. These lines are usually PVC and are usually buried with individual risers to the ground surface for each lateral line. The lateral lines lead off from one or both sides of the manifold depending on the system layout. Pipe size usually runs from 1/2 to 1 inch in diameter.

8. Lateral Lines

These lines, leading away from the manifold, carry the water along the rows of trees, shrubs, or other plants being irrigated. The lines are usually 1/2 inch diameter, except 3/4 inch may be required on some of the larger systems depending on row length, amount of flow, terrain characteristics, and other related factors. They are usually laid on the ground surface. Underground or buried lateral lines are much more expensive but may be desirable depending upon the type of system being installed. For stem crops, one lateral line is usually run down each row next to the stems. For row crops the lateral is used as a header to supply water to the tubing which is run down each row.

9. Emitters or Mechanical Outlets

a. For stem crops such as trees and shrubs use emitters, drippers, applicators, orifices, etc., to apply water to the plant. Ordinarily, one to six are used per plant. Delivery rate depends on the size and operating pressure. (Note: For low head installations, micro-tubing can be used in lieu of emitters, etc. The amount of water applied is regulated by the length of tubing at each plant.)

b. For row crops use porous tubing, perforated pipe, multi-passage tubing, etc. Usually one line is laid down each row.

10. Drains

a. Drain valves or plugs should be installed at all low points in the system.

b. Drain plugs should be installed at the end of the manifold and the lateral lines. This will permit drainage and also periodic flushing of the system.

11. Other

a. Lateral lines installed along the ground surface should be "snaked" along the rows. This allows for contraction and expansion due to temperature changes. Five to ten percent is usually added to compensate for this.

b. Five to ten extra feet should be added to the end of the manifold and laterals (beyond last emitter). This provides temporary storage for sediments which may get past the filter(s). These may be flushed out periodically.

c. Cutoff valves installed at the front of each lateral line permit greater flexibility in system operation. Individual lines can be shut off for repair and maintenance while the remainder of the system operates. The valves also help when flushing the system or when injecting fertilizer or chemicals.

d. Fixtures (pressure regulators, gages, filters, etc.) should be mounted off of the ground surface to prevent breakage. Install guard posts as needed to protect fixtures from machinery, livestock, etc.

C. Design Criteria

1. Survey and Other Data Needed

a. See the Kansas Note Keeping and Documentation Manual, Part 585, for instructions on the type of surveys needed.

b. Tree or shrub spacing and also row width, length, and direction.

c. Water source, pressure, quantity, and quality.

d. Type of soil. (Soil characteristics will determine the water application rates, frequency of irrigation, etc., the same as for any other method of irrigation.)

2. Design Considerations

a. Depending on conditions, it is usually desirable to start with 25 to 30 psi water pressure at the source. If necessary, use a pressure regulator to maintain this starting pressure.

b. When sizing the main line and laterals, try to hold the pressure drop across any lateral to 10 psi or less when the system is operating. This will result in a more uniform emitter discharge.

3. System Design

a. Refer to the Kansas Standard for Irrigation System, Drip - 441.

b. Net application:

$$Fn = 1.604 \frac{QNTE}{AF}$$

where:

Fn = Net application depth in inches per day.

Q = Discharge in gallons per hour per emitter or per foot

N = Number of mechanical outlets (emitters, orifices, etc.) or total footage of tubing

T = Hours of operation per day

E = Field application efficiency expressed as a decimal (80 to 90% efficiency may be used)

A = Square feet of field area served by N or total footage of tubing

F = The design area as a percentage of the field area, expressed as a decimal

1.604 = Units conversion constant (12 in./ft./7.48 gal./cu. ft.)

D. System Design Using Form KS-ENG-428(JS)

1. Plot ground elevation shots on the profile view of the main line, manifold, and lateral line which represents the maximum operating condition for the system. Usually this will be the longest lateral line, carrying the most flow, and with the most uphill elevation difference. Sometimes it may be necessary to make more than one design to determine this condition. List row number and plotting scale under the profile view. For very simple systems (50 gph or less and 300 feet or less individual lateral length) with less than 5 feet elevation difference it may not be necessary to plot the hydraulic grade line.

2. Under the Hydraulic Design Data Section list:

a. Total system Q in gallons per hour (gph) and gallons per minute (gpm).

b. Water pressure and elevation at the hydrant or source in pounds per square inch (psi) along with the ground elevation at this location.

c. Convert psi to feet of head by multiplying psi x 2.31. Add the feet of head to the ground elevation at the source to obtain the elevation of the hydraulic grade line (H.G.L.) at this point. Enter the Q and H.G.L. on the first line of the design table.

d. Select a main line pipe size for Reach A. The size will usually run from 3/4 to 1½ inch diameter for most systems. Find the friction or head loss for Reach A for the Q being carried. If in psi, multiply by 2.31 to convert to feet of head loss. List all of this information in the design table on the line for Reach A. Subtract the head loss in feet for this reach from the H.G.L. elevation at the source. This gives the H.G.L. elevation at the end of Reach A or at the start of Reach B.

e. Reach B is the first section of the manifold. The length will equal the row spacing if the manifold is buried, or row spacing plus 5 percent (for expansion and contraction) if the manifold is installed on the ground surface. Select a pipe size (usually 3/4 inch) for the manifold. Subtract the gph going to the first row from the total Q to find the Q carried by Reach B. Find the head loss (psi and feet) for Reach B. Subtract the head loss in feet from the H.G.L. elevation at end of Reach A (beginning of Reach B) and list in the table of the line for Reach B along with the pipe diameter, Q, reach length, psi, and feet of head loss. This will be the H.G.L. elevation at the end of Reach B or the start of Reach C.

f. Continue the above sequence for each section or reach of the manifold until the row representing the maximum condition is reached. Usually this will be the outside row, but may be the longest row or the one with the most uphill elevation difference.

g. Select the lateral tubing size. Usually ½-inch diameter tubing will work on row lengths of 500 feet or less. Determine the head loss (psi and foot) across the lateral for the gph to be carried. Subtract this from the H.G.L. elevation at the beginning of the lateral which gives the elevation of the H.G.L. at the end of the line.

3. Plot the H.G.L. for the system on the profile view using the values from the design table for the different locations along the system. Subtract the ground elevations at each location from the H.G.L. which shows the pressure head available at that point. Divide the pressure head in feet by 2.31 to obtain psi. Check all high points to make sure there is sufficient pressure available so the emitters will operate properly. Usually anything less than 10 psi would be reason enough to revise the design.

E. Pipe Friction Values to Use in Trickle Irrigation Design

1. Due to the wide variance and lack of standardization of pipe diameters by the different manufacturers, it is preferable to use their friction values in lieu of standard data if known. If not, use the head loss tables issued by SCS (J values for friction loss per 100 feet - see page 5A-10).

2. A notation should be made on the plans as to what criteria was used in the design.

3. Sample Problem - Use Pepco design criteria. Reference sample design, Form KS-ENG-428(JS), (fig. 5A-2).

a. Given: Five-row windbreak - 500-foot row length, 525-foot lateral length
Emitters - Row 1 - 85 on 6-foot spacing, Rows 2, 3, 4, and 5 - 50 each on 10-foot spacing
Total = 285 - pressure compensating, 1 gph flow rating
Main line - L = 100 feet; Manifold - L = 100 feet, 25-foot row spacing
Q = 285 gph or 4.75 gpm
Pressure at water source = 30 psi, Elevation at source = 49.2

b. Solution:

(1) Draw plan view of windbreak as shown on sample plan.

(2) Plot ground profile as shown on sample plan.

(3) Assume maximum condition will be at the end of Row 1 when the system is operating.

(4) Fill in Hydraulic Design Data, Q = 285 gph, 4.75 gpm; water source pressure = 30 psi; and elevation at source = 49.2.

(5) Multiply 30 psi x 2.31 = 69.3 feet. Add this to the ground elevation at the source (49.2) = 118.5, elevation of H.G.L. at the hydrant or source. On line 1 of the design table, list "Source" under reach, 285 gph under "Q" and 118.5 under "H.G.L."

(6) Select a 3/4-inch diameter pipe (P - 940, I.D. = 0.80 inches, Pepco) for Reach A. From graph 6, Pepco data, determine friction loss for l = 100 feet, Q = 4.75 gpm, loss = 0.23 psi/10 feet x 10.0 = 2.30 psi x 2.31 = 5.3 feet. Subtract 5.3 feet from the elevation of the H.G.L. at the source (118.5) = 113.2 = H.G.L. elevation at the end of Reach A or the start of the manifold. List pipe size, Q, L, psi loss, feet loss, and H.G.L. on line 2, Reach A of the design table.

(7) Select 3/4-inch diameter pipe (P - 940, I.D. = 0.80 inches, Pepco) for manifold. Reach B length = 25 feet (row spacing). 35 - 50 (Q for row 5) = 235 gph being carried by Reach B. From 6, Pepco data, determine friction loss for l = 25 feet, Q = 235 92 gpm, loss - 0.172 psi/10 feet x 2.5 = 0.43 psi x 2.31 = 1.0 btract 1.0 foot from the elevation of the H.G.L. at the start ach (113.2) = 112.2, H.G.L. elevation at the end of Reach B or Reach C. List pipe size, Q, L, psi loss, feet loss, and H.G.L. , Reach B of the design table.

(8) Compute the friction losses for each of the remaining reaches of the manifold as follows using graph 6, Pepco data:

<u>Reach C</u> - Q = 235 - 50 = 185 gph = 3.08 gpm, loss = 0.12 x 2.5 = 0.3 psi x 2.31 = 0.7 foot, H.G.L. = 111.5

<u>Reach D</u> - Q = 185 - 50 = 135 gph = 2.25 gpm, loss = 0.058 x 2.5 = 0.15 psi x 2.31 = 0.3 foot, H.G.L. = 111.2

<u>Reach E</u> - Q = 135 - 50 = 85 gph = 1.42 gpm, loss = 0.021 x 2.5 = 0.05 psi x 2.31 = 0.1 foot, H.G.L. = 111.1

(9) Compute friction loss in row 1, Q = 85 gph, l = 525 feet, use ½-inch diameter (P - 704, I.D. = 0.58 inches, Pepco) tubing, average flow per foot = AFPF

$$\text{AFPF} = \frac{\text{(No. of emitters) (emitter flow rate)}}{\text{Length of lateral}}$$

$$= \frac{85 \times 1}{525} = 0.16 = \text{AFPF}$$

Enter graph 2, Pepco data, with l = 525 feet, AFPF = 0.16, P - 704 tubing loss = 2.3 psi x 2.31 = 5.3 feet
H.G.L. at end of row 1 = 111.1 - 5.3 = 105.8

(10) Plot the H.G.L. for the system on the profile view using the elevations from the design table for the various locations along the system.

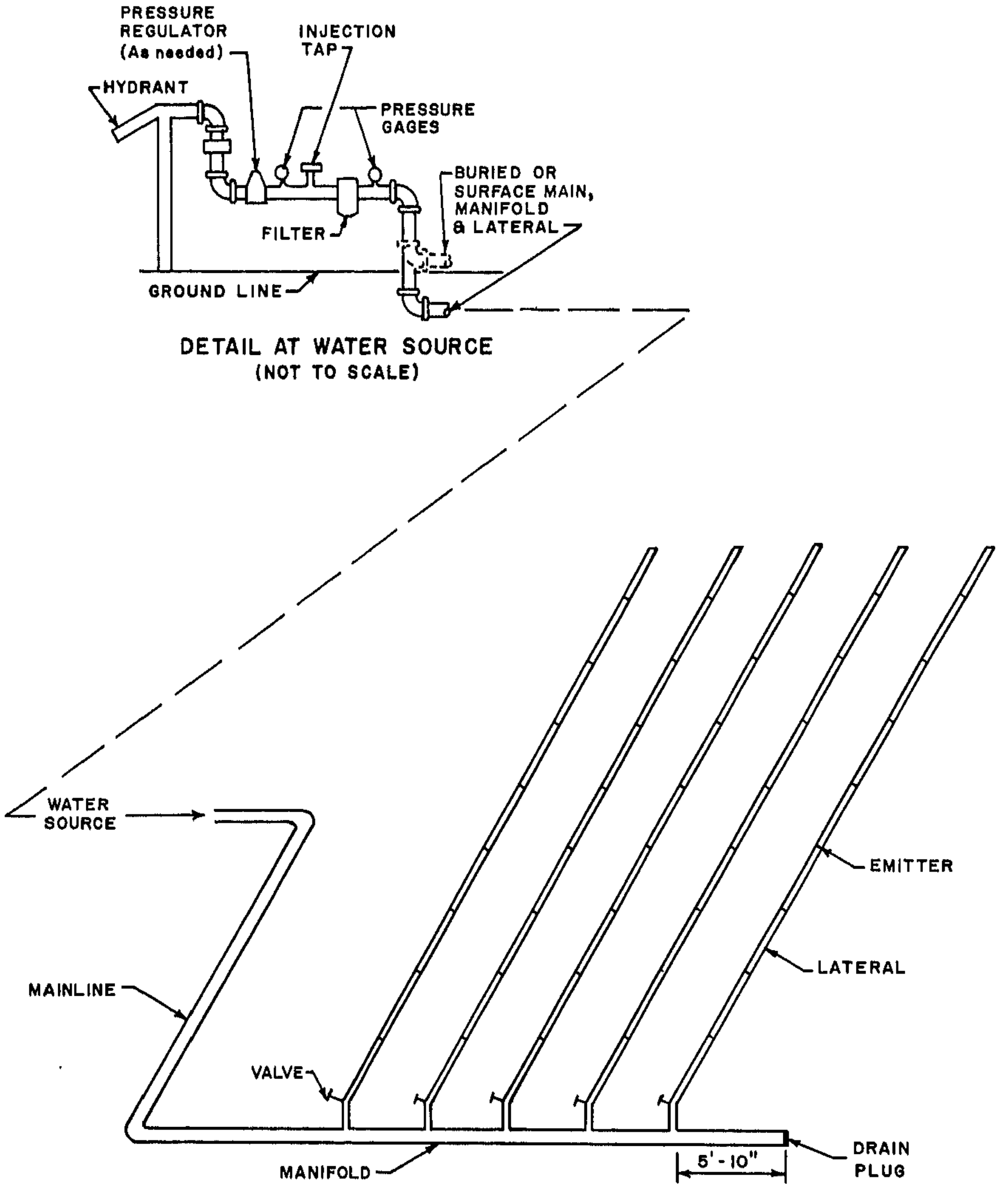
(11) Compute pressure head at following points along the system:

Station 1+00 (end of Reach A) = (H.G.L. - ground elevation) ÷ 2.31
= (113.2 - 50.0) ÷ 2.31 = 27.4 psi
Station 2+00 (end of Reach E) = (111.1 - 50.4) ÷ 2.31 = 26.3 psi
Station 7+00 (end of Reach F) = (105.8 - 61.0) ÷ 2.31 = 19.4 psi

(12) System analysis

(a) Pressure is adequate to properly operate all emitters in system.

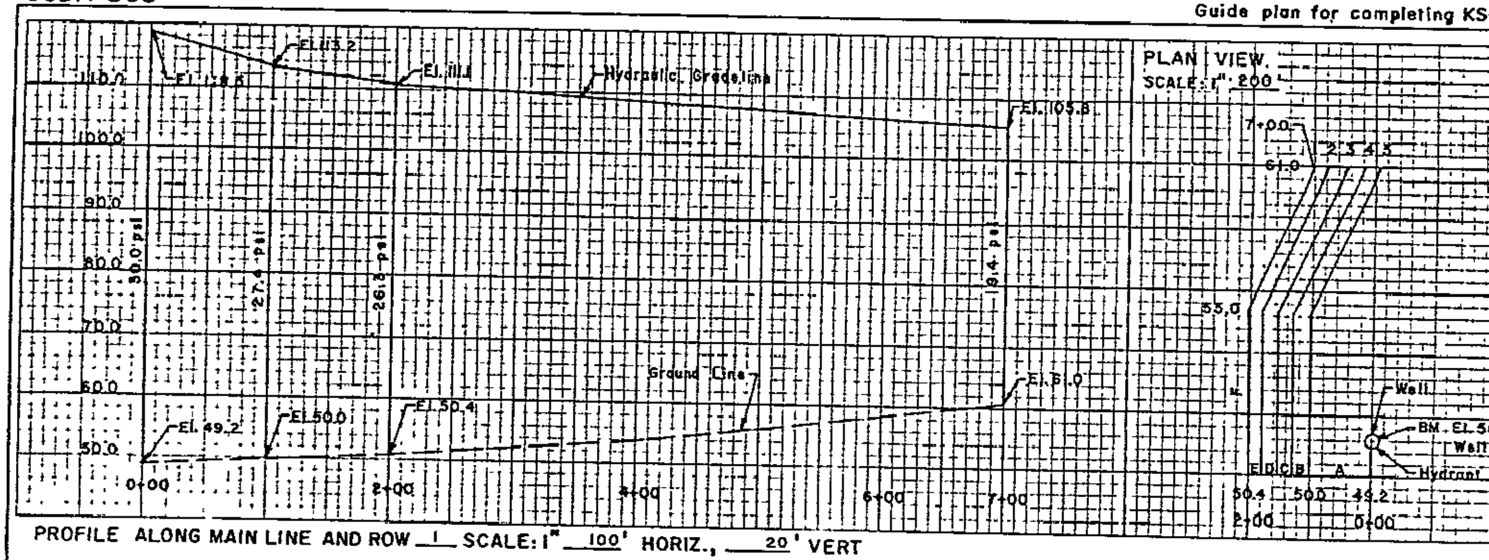
(b) Pressure drop across row 1 (2.3 psi) is less than 10 psi.



COMPONENTS OF A TRICKLE IRRIGATION SYSTEM

USDA-SCS

Guide plan for completing KS-ENG-428 (JS),

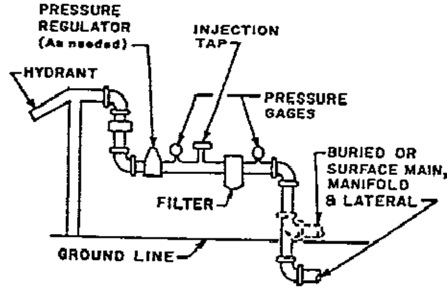


ROW		EMITTERS		
No.	L	No.	gph	Spac.
1	500'	85	1	6'
2		50		10'
3				
4				
5	↓	↓	↓	↓

PROFILE ALONG MAIN LINE AND ROW 1 SCALE: 1" 100' HORIZ., 20' VERT

HYDRAULIC DESIGN DATA: TOTAL SYSTEM Q= 285 gph 4.75 gpm
WATER SOURCE PRESSURE 30 psi EL. @ SOURCE 49.2

REACH	PIPE SIZE IN	Q G.P.M.	REACH LENGTH FT	LOSS P.S.I.	LOSS FEET	ELEV. OF H.G.L.
Source	—	285	—	—	—	118.5
A	3/4	285	100	2.30	5.3	113.2
B	3/4	235	25	0.43	1.0	112.2
C	3/4	185	25	0.30	0.7	111.5
D	3/4	135	25	0.15	0.3	111.2
E	3/4	85	25	0.05	0.1	111.1
F	1/2	85	525	2.30	5.3	105.8



DETAIL AT WATER SOURCE
(NOT TO SCALE)

TABLE OF QUANTITIES

ITEM	UNIT	QUAN.
Tubing, 3/4" dia. (P-940)* main & manifold	Lin.Ft.	205
Tubing, 1/2" dia. (P-740)* laterals	Lin.Ft.	2,650
Emitters-1 gph-pressure compensating	Ea.	285
Filter-100 mesh	Ea.	1
Pressure regulator-30 psi	Ea.	1
Pressure gage-100 psi	Ea.	2
Flushing plug-manual-3/4" dia	Ea.	1
Flushing plug-manual-1/2" dia.	Ea.	5
Non-freeze hydrant-3/4" dia.	Ea.	1
Line valves-1/2" dia.	Ea.	5
Injector tap w/fittings	Ea.	1
Couplings, tees & fittings as needed		
* Pepco or equivalent		

INSTALLATION NOTES:

1. Bury main and manifold (Min. 30")
2. Install lateral lines on ground surface, allow 5% extra for temperature expansion and contraction.
3. Install line valves at start of each lateral line.
4. Add 5' of tubing to the end of each lateral line and the manifold for temporary sediment storage.
5. See attached KA-PS-6 for windbreak details.
6. Pepco criteria used for design.

1. OPERATE SYSTEM WITHIN THE FOLLOWING PRESSURE LIMITS MAX. 30 PSI, MIN. 20 PSI.
2. APPLY APPROX. 2 GAL./PLANT/WEEK 1st YR., 4 GAL.-2nd YR., 5 GAL.-3rd YR.-(Apply 5 gal Every Two Weeks After 3 Years)
3. FLUSH LINE PERIODICALLY (MINIMUM TWICE PER SEASON)
4. CLEAN OR FLUSH FILTERS WEEKLY OR AS NEEDED.
5. REMOVE FILTERS AND OTHER FIXTURES BEFORE FREEZING WEATHER. FOLLOW MANUFACTURER'S INSTRUCTIONS ON NEED TO DRAIN SYSTEM.

Rev. 12/82

TRICKLE IRRIGATION SYSTEM
OWNER EXAMPLE
LEGAL DESC.____ SEC.____ T____ R____
________ COUNTY, KANSAS

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Designed ____ Date ____ Approved by ____
Drawn ____ Title ____
Traced ____ Sheet ____ Drawing No. ____
Checked ____

U.S. Government Printing Office 1981 — 767 361 SCS ENG 313A REV 8 75

Figure 5A-2 Sample of Trickle Irrigation Design

Table 5A.1

Head Loss for Trickle Irrigation Tubing

I.D. = 0.58"

gph	J	gph	J	gph	J	gph	J
1	0.001	43	0.99	85	3.25	127	6.57
2	0.005	44	1.03	86	3.32	128	6.66
3	0.01	45	1.07	87	3.39	129	6.75
4	0.02	46	1.11	88	3.46	130	6.84
5	0.02	47	1.15	89	3.53	131	6.93
6	0.03	48	1.20	90	3.60	132	7.03
7	0.04	49	1.24	91	3.67	133	7.12
8	0.05	50	1.28	92	3.74	134	7.22
9	0.06	51	1.33	93	3.81	135	7.31
10	0.08	52	1.38	94	3.88	136	7.40
11	0.09	53	1.42	95	3.95	137	7.50
12	0.11	54	1.47	96	4.03	138	7.60
13	0.12	55	1.52	97	4.10	139	7.69
14	0.14	56	1.57	98	4.17	140	7.79
15	0.16	57	1.62	99	4.25	141	7.89
16	0.18	58	1.67	100	4.32	142	7.99
17	0.20	59	1.72	101	4.40	143	8.08
18	0.22	60	1.77	102	4.48	144	8.18
19	0.24	61	1.82	103	4.55	145	8.28
20	0.26	62	1.87	104	4.63	146	8.38
21	0.28	63	1.93	105	4.71	147	8.48
22	0.30	64	1.98	106	4.79	148	8.59
23	0.33	65	2.03	107	4.87	149	8.69
24	0.36	66	2.09	108	4.95	150	8.79
25	0.38	67	2.15	109	5.03	151	8.89
26	0.41	68	2.20	110	5.11	152	9.00
27	0.44	69	2.26	111	5.19	153	9.10
28	0.47	70	2.32	112	5.27	154	9.20
29	0.50	71	2.37	113	5.35	155	9.31
30	0.53	72	2.43	114	5.44	156	9.41
31	0.56	73	2.49	115	5.52	157	9.52
32	0.59	74	2.55	116	5.61	158	9.63
33	0.62	75	2.61	117	5.69	159	9.73
34	0.65	76	2.67	118	5.78	160	9.84
35	0.69	77	2.74	119	5.86	161	9.95
36	0.72	78	2.80	120	5.95	162	10.06
37	0.76	79	2.86	121	6.04	163	10.17
38	0.80	80	2.93	122	6.12	164	10.27
39	0.83	81	2.99	123	6.21	165	10.38
40	0.87	82	3.05	124	6.30	166	10.50
41	0.91	83	3.12	125	6.39	167	10.61
42	0.95	84	3.19	126	6.48	168	10.72

Based on the equation

$$J = 0.133 \frac{Q^{1.75}}{I.D.^{4.75}}$$

J = Pipe friction loss ft./100 ft. of tubing
Q = Flow rate in gallons/minute (gpm)
I.D. = Inside diameter of tubing, inches
gph = gallons/hour

Table 5A.1 (Continued)

I.D. = 0.80"

Flow		J	Flow		J	Flow		J
gph	gpm		gph	gpm		gph	gpm	
2	0.03	0.001	82	1.37	0.66	162	2.70	2.18
4	0.06	0.003	84	1.40	0.69	164	2.73	2.23
6	0.10	0.007	86	1.43	0.72	166	2.77	2.28
8	0.13	0.01	88	1.47	0.75	168	2.80	2.33
10	0.17	0.02	90	1.50	0.78	170	2.83	2.38
12	0.20	0.02	92	9.53	0.81	172	2.87	2.42
14	0.23	0.03	94	1.57	0.84	174	2.90	2.47
16	0.27	0.04	96	1.60	0.87	176	2.93	2.52
18	0.30	0.05	98	1.63	0.91	178	2.97	2.57
20	0.33	0.06	100	1.67	0.94	180	3.00	2.63
22	0.37	0.07	102	1.70	0.97	182	3.03	2.68
24	0.40	0.08	104	1.73	1.01	184	3.07	2.73
26	0.43	0.09	106	1.77	1.04	186	3.10	2.78
28	0.47	0.10	108	1.80	1.07	188	3.13	2.83
30	0.50	0.11	110	1.83	1.11	190	3.17	2.89
32	0.53	0.13	112	1.87	1.14	192	3.20	2.94
34	0.57	0.14	114	1.90	1.18	194	3.23	2.99
36	0.60	0.16	116	1.93	1.22	196	3.27	3.05
38	0.63	0.17	118	1.97	1.25	198	3.30	3.10
40	0.67	0.19	120	2.00	1.29	200	3.33	3.16
42	0.70	0.21	122	2.03	1.33	202	3.37	3.21
44	0.73	0.22	124	2.07	1.37	204	3.40	3.27
46	0.77	0.24	126	2.10	1.41	206	3.43	3.32
48	0.80	0.26	128	2.13	1.45	208	3.47	3.39
50	0.83	0.28	130	2.17	1.49	210	3.50	3.44
52	0.87	0.30	132	2.20	1.53	212	3.53	3.50
54	0.90	0.32	134	2.23	1.57	214	3.57	3.55
56	0.93	0.34	136	2.27	1.61	216	3.60	3.61
58	0.97	0.36	138	2.30	1.65	218	3.63	3.67
60	1.00	0.38	140	2.33	1.69	220	3.67	3.73
62	1.03	0.41	142	2.37	1.73	222	3.70	3.79
64	1.07	0.43	144	2.40	1.78	224	3.73	3.85
66	1.10	0.45	146	2.43	1.82	226	3.77	3.91
68	1.13	0.48	148	2.47	1.86	228	3.80	3.97
70	1.17	0.50	150	2.50	1.91	230	3.83	4.03
72	1.20	0.53	152	2.53	1.95	232	3.87	4.09
74	1.23	0.55	154	2.57	2.00	234	3.90	4.15
76	1.27	0.58	156	2.60	2.04	236	3.93	4.22
78	1.30	0.61	158	2.63	2.09	238	3.97	4.28
80	1.33	0.64	160	2.67	2.14	240	4.00	4.34

Based on the equation:

$$J = 0.133 \frac{Q^{1.75}}{I.D.^{4.75}}$$

J = Pipe friction loss, ft./100 ft. of tubir
Q = Flow rate in gallons/minute (gpm)
I.D. = Inside diameter of tubing, inches
gph = gallons/hour

Table 5A.1 (Continued)

I.D. = 0.80"

Flow gph	Flow gpm	J	Flow gph	Flow gpm	J	Flow gph	Flow gpm	J
242	4.03	4.41	322	5.37	7.26	402	6.70	10.71
244	4.07	4.47	324	5.40	7.34	404	6.73	10.80
246	4.10	4.53	326	5.43	7.42	406	6.77	10.90
248	4.13	4.60	328	5.47	7.50	408	6.80	10.99
250	4.17	4.66	330	5.50	7.58	410	6.83	11.09
252	4.20	4.73	332	5.53	7.66	412	6.87	11.18
254	4.23	4.80	334	5.57	7.74	414	6.90	11.28
256	4.27	4.86	336	5.60	7.83	416	6.93	11.37
258	4.30	4.93	338	5.63	7.91	418	6.97	11.47
260	4.33	5.00	340	5.67	7.99	420	7.00	11.56
262	4.37	5.06	342	5.70	8.07	422	7.03	11.66
264	4.40	5.13	344	5.73	8.15	424	7.07	11.76
266	4.43	5.20	346	5.77	8.24	426	7.10	11.85
268	4.47	5.27	348	5.80	8.32	428	7.13	11.95
270	4.50	5.34	350	5.83	8.40	430	7.17	12.05
272	4.53	5.41	352	5.87	8.49	432	7.20	12.15
274	4.57	5.48	354	5.90	8.57	434	7.23	12.25
276	4.60	5.55	356	5.93	8.66	436	7.27	12.35
278	4.63	5.62	358	5.97	8.74	438	7.30	12.44
280	4.67	5.69	360	6.00	8.83	440	7.33	12.54
282	4.70	5.76	362	6.03	8.92	442	7.37	12.64
284	4.73	5.83	364	6.07	9.00	444	7.40	12.74
286	4.77	5.90	366	6.10	9.09	446	7.43	12.85
288	4.80	5.98	368	6.13	9.18	448	7.47	12.95
290	4.83	6.05	370	6.17	9.26	450	7.50	13.05
292	4.87	6.12	372	6.20	9.35	452	7.53	13.15
294	4.90	6.19	374	6.23	9.44	454	7.57	13.25
296	4.93	6.27	376	6.27	9.53	456	7.60	13.35
298	4.97	6.34	378	6.30	9.62	458	7.63	13.46
300	5.00	6.42	380	6.33	9.71	460	7.67	13.56
302	5.03	6.49	382	6.37	9.80	462	7.70	13.66
304	5.07	6.57	384	6.40	9.89	464	7.73	13.77
306	5.10	6.64	386	6.43	9.98	466	7.77	13.87
308	5.13	6.72	388	6.47	10.07	468	7.80	13.97
310	5.17	6.80	390	6.50	10.16	470	7.83	14.08
312	5.20	6.87	392	6.53	10.25	472	7.87	14.18
314	5.23	6.95	394	6.57	10.34	474	7.90	14.29
316	5.27	7.03	396	6.60	10.43	476	7.93	14.40
318	5.30	7.11	398	6.63	10.52	478	7.97	14.50
320	5.33	7.18	400	6.67	10.62	480	8.00	14.61

Based on the equation:

$$J = 0.133 \frac{Q^{1.75}}{I.D.^{4.75}}$$

J = Pipe friction loss, ft./100 ft. of tubing
Q = Flow rate in gallons/minute (gpm)
I.D. = Inside diameter of tubing, inches
gph = gallons/hour

Table 5A.2

Friction Loss in Pipe with **Multiple Outlets**

F = Reduction coefficient

N = Number of outlets

$$F = 0.351 + \frac{1}{2N} + \frac{0.154}{N^2}$$

N No. of Outlets	F Reduction Coefficient	N No. of Outlets	F Reduction Coefficient
1	1.000	12	0.394
2	0.639	13	0.390
3	0.535	14	0.388
4	0.486	15	0.385
5	0.457	16-17	0.382
6	0.439	18-20	0.378
7	0.426	21-26	0.373
8	0.416	27-35	0.366
9	0.408	36-55	0.362
10	0.403	56-125	0.357
11	0.398	>126	0.355

Friction loss for pipe with multiple outlets = F x J x L
where F = Reduction coefficient
J = Friction loss, ft./100 ft.
L = Length in 100's of feet

Example: Q = 50 gph, I.D. = 0.58 inch, L = 500 feet, N = 50
Friction loss = F x J x L = 0.362 x 1.28 x 5 = 2.3 feet

F. Field Evaluation of Trickle Irrigation Systems

An acceptable method for field evaluation of trickle irrigation systems is as follows:

1. Determine the lateral line from the plan sheet (Form KS-ENG-428(JS)) which represents the maximum operating condition when the system is being used. This is usually the most limiting factor as related to the proper functioning of the system. Ordinarily it will be the longest lateral with the most emitters and the least downhill elevation head when the system is operating.

2. On windbreaks, checking the lateral line representing the maximum condition will usually be sufficient for the average size system. On orchards and vineyards, a random sample of 10 percent of the lateral lines will be adequate. On all systems, a visual check should be made on an additional 10 percent of the other lateral lines. Visual checks should also be made of the major component parts of the system (pressure gages, line valves, filters, etc.) to insure there are no obvious problems that need attention.

3. Place catch cans or containers under six emitters along the lateral line selected for checking. They should be placed at random locations along the line. Generally, more satisfactory results are obtained if the first one or two and the last two or three emitters are not used. High or low elevations along the line should be included in the checking.

4. Time the flow into the catch cans or containers for a minimum of 15 minutes. A stop watch with a second hand should be used for timing.

5. Record the amount of water caught if the catch can or container is calibrated. If not, pour the water into a graduated cylinder or other measuring vessel. Use the following conversion factors (depending on the units the water is measured in) to convert the measured quantities to emitter flow rate in gallons per hour (gph). Multiply the quantity of water (gallons, milliliters, etc.) by the factor (F).

Time in Minutes	Quantity Units	X	Factor (F) = gph
15	Milliliters		0.001057
15	Fluid Ounces		0.03125
15	Gallons		4
20	Milliliters		0.0007925
20	Fluid Ounces		0.023437
20	Gallons		3

6. The emitter discharge in gallons per hour (gph) should check within ± 15 percent of the average flow of the six emitters. Either the highest or lowest flow rate may be thrown out if the total amount of the six emitters does not average out to within ± 15 percent.

Example: Using a 15-minute time interval the following amounts of water were measured:

Emitter No.	Units	Quantity	Factor	gph
1	ml	950	0.001057	1.004
2	ml	970	0.001057	1.025
3	ml	1,000	0.001057	1.057
4	ml	1,150	0.001057	1.216
5	ml	920	0.001057	0.972
6	ml	890	0.001057	0.941

Average flow = $\frac{6.215}{6}$ = 1.036 gph

Upper tolerance limit = 1.036 x 1.15 = 1.191 gph
Lower tolerance limit = 1.036 x 0.85 = 0.881 gph

In this case, emitter no. 4 exceeds the maximum. By omitting this emitter the average flow rate for the other five emitters would be 0.999 gph. The upper limit would then be 1.148 gph and the lower limit 0.849. The five emitters would then meet the required tolerance.

7. In cases where the flow rates do not meet the tolerances, there are several items that should be checked. They are:

a. Double check at the hydrant or water source and make sure the system is operating at the design pressure. Remove one of the pressure gages and use a different gage to check the pressure. This should be done if there is any question as to the accuracy of the ones being used.

b. Be sure line valves are set correctly and functioning properly.

c. Take pressure checks at th
sure there are no blockages in the latera
pressure is to remove the emitter and ins
gage, or a special fitting can be fabrica
the designed operating pressure at these
system plan.)

d. Check the next most critic
meets the design requirements. If it che
assumed the remainder of the lateral line

e. Emitters that are obviousl
and a new test should be run.

f. In extreme cases it may be necessary to run a supplemental lateral line and bypass the trouble spot in the line if it can be located.

g. If there is any question as to emitter clogging, the clogging agent should be definitely identified before any corrective action is taken.

FIELD SHEET: TRICKLE IRRIGATION SYSTEM EVALUATION

Owner Example Ident. No. ______
Legal Descr. ______ County ______

System Installation Date 8/4/82 Water Source House Well
Total System Q 285 gph Pressure @ Source 30 psi
Pipe Dia: Main 3/4 in. Manifold 3/4 in. Lateral (s) 1/2 in.
Emitter Type Press. Comp. Mfg. & Model Global-STTF* Q 1.0 gph
Maximum Condition: Lateral No. 1 Pipe Dia. 1/2 in.

Sta.	Time (min.)	Amount Measured	Units	Factor F	Calculated gph
2+24	15	950	ml	0.001057	1.004
2+72	↓	970	↓	↓	1.025
3+26	↓	1,000	↓	↓	1.057
3+74	↓	1,150	↓	↓	1.216
4+28	↓	920	↓	↓	0.972
4+82	↓	890	↓	↓	0.941
				Total	6.215
				Avg. Flow	1.036

Upper Tolerance Limit = 1.191 gph

Lower Tolerance Limit = 0.881 gph

Conversion Factors		
T Minutes	Measured Units	F Factor
15	Milliliters	0.001057
15	Fluid Ounces	0.03125
15	Gallons	4
20	Milliliters	0.0007925
20	Fluid Ounces	0.023437
20	Gallons	3
gph = Amount Measured XF		

Remarks:

By omi
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______
System Ev

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Title

PART 6 - DESIGN TABLES AND THEIR USE

The irrigation design group sheets, Part 4, give design data for the various soils listed in the guide. However, many times the conditions encountered will not be identical to the conditions on which the data for these sheets were based. For example, a given field may be 1000 feet long whereas the irrigation design sheet may state the maximum length of run to be 1400 feet. In such cases an adjustment needs to be made. It may involve reducing the stream size, changing the time of application or reducing the net application of water applied. It could also be a combination of all these items.

This guide contains several tables for making these adjustments which will eliminate, in most cases, the need of performing many computations. A summary of which tables to use for the various methods of irrigation follows.

A. Border Irrigation

1. Level - Table 6.1, page 6-3, is to be used to arrive at relationships for unit stream, length of level borders, and net irrigation application. The "n" values are shown at the top of Table 6.1. A slightly greater flow depth is permissible for alfalfa and grass than for small grain which sufficiently offsets "n" value variation so that one table is suitable for values of minimum unit stream (q) and maximum length of run (L) for these crops. Using a "q" value greater than the minimum shown will decrease application time proportionately.

   After determining the desired "q" applicable to net application adapted to the length of border encountered, Table 6.7, page 6-8, may be used to compute the time required to apply the water to each border. Multiply the gross number of inches to be applied by the time in minutes from the chart for the applicable irrigation stream to obtain the time to apply the irrigation.

   Table 6.2, page 6-4, gives the flow depths of water for various crops as related to size of irrigation stream and border length. The ratio Q/W or irrigation stream per foot width of border is determined by dividing the stream (c.f.s.) turned into the border by the width of the border being watered by that stream. It can also be determined by multiplying the unit stream from Table 6.1

by the border length in 100 feet units (i.e. 2600 ft. = 26 units each 100 feet long). This information is useful in determining the height for the field borders. A minimum freeboard of 0.2 foot should also be provided.

2. Graded - Tables 6.3 and 6.4, pages 6-5 and 6-6, can be used to determine the relationships for unit stream and length of run for graded borders. In addition, Table 6.3 gives the time required to apply the water and the efficiency which is possible to attain for various amounts of net application.

   Table 6.5, page 6-7, shows unit stream sizes with respect to their limitations with graded borders. Using stream sizes smaller than the minimum will result in inadequate spreading. Using streams larger than the maximum may cause erosion.

   Table 6.6, page 6-7, giving flow depths for various sized streams, may be used to determine required height of border dikes. (A minimum freeboard of 0.2 foot should also be provided.) The ratio of Q/W is found as for level borders.

   Table 6.7, page 6-8, can also be used for graded borders. It gives time required to apply 1.0 inch of water using different size unit streams.

B. Furrow Irrigation

Tables 6.8 and 6.9, pages 6-9 and 6-10, may be used to determine design for lengths and for furrow spacings other than those contained in the design work sheets. Combinations of various stream sizes "q" can be matched with various net depths of application "f" to arrive at the most satisfactory design.

Table 6.11, page 6-12, gives a conversion table to change intake rates or application rates from g.p.m. per 100 feet of furrow to inches per hour, or to change inches per hour to g.p.m. per 100 feet.

The needed opportunity time (T_o) is also given. Acceptable operating schedules for various values of T_o and time to apply gross application (T_A) are given in Table 6.12, page 6-13.

Table 6.14, page 6-14, lists clock times which work well with the operating schedules.

Table 6.1

Maximum Length-Minimum "q" Relationship for Level Borders

Applying Various Net Applications

Alfalfa and Grass n = .15
Small grain n = .10

Design Efficiency - 80%

Design Groups 3 and 4 (0.3 Intake Family)

2.0 In.		3.0 In.		4.0 In.		5.0 In.	
Min. q	Max. L	Min. q	Max. L	Min. q	Max. L	Min. q	Max. L
.0035	400	.0025	700	.0019	1000	.0015	1200
.0047	600	.0029	900	.0022	1200	.0017	1500
.0058	800	.0033	1100	.0024	1400	.0018	1700
.0070	1000	.0037	1300	.0026	1600	.0020	1900
.0080	1200	.0041	1500	.0028	1800	.0021	2100

Design Groups 5 and 6 (0.5 Intake Family)

2.0 In.		3.0 In.		4.0 In.		5.0 In.	
Min. q	Max. L	Min. q	Max. L	Min. q	Max. L	Min. q	Max. L
.0080	400	.0050	600	.0040	800	.0033	1000
.0110	600	.0064	800	.0045	1000	.0035	1250
.0140	800	.0074	1000	.0050	1200	.0039	1400

Design Groups 7 and 8 (1.0 Intake Family)

2.0 In.		3.0 In.		4.0 In.		5.0 In.	
Min. q	Max. L	Min. q	Max. L	Min. q	Max. L	Min. q	Max. L
.018	300	.011	400	.008	500	.0064	600
.023	400	.014	500	.009	650	.0073	750
.030	500	.016	650	.011	750	.0080	850

Design Groups 9 and 10 (1.5 Intake Family)

2.0 In.		3.0 In.		4.0 In.		5.0 In.	
Min. q	Max. L	Min. q	Max. L	Min. q	Max. L	Min. q	Max. L
.025	200	.015	300	.012	400	.009	450
.034	300	.019	400	.014	500	.010	550
.045	400	.023	500	.017	600	.012	650

Maximum length based on maximum flow depth of 0.5 ft. for alfalfa and grass and 0.4 ft. for small grain and distance water will travel during 0.5 opportunity time.

Example of Use: Design Group 5. Net application 4.0 inches, then maximum border length is 1200 feet and minimum unit stream for this length is .005 cfs.

Table 6.2

Level Border Flow Depths "d_1" in Feet for Various

Irrigation Streams Q/W, and Border Lengths

$$d_1 = 0.833(N)^{.462}(Q/W)^{.462}L^{.231}$$

Border Length	Irrigation Stream Q/W .03	.04	.05	.06	.07	.08	.09	.10	.12	.14	.16	.18	.20
Small Grain n = .10													
200	.19	.22	.24	.27	.28	.30	.32	.33	.36	.39	.42	.44	.46
300	.21	.24	.27	.29	.32	.33	.35	.37	.40	.43	.46	.48	.51
400	.22	.26	.29	.32	.34	.36	.38	.40	.44	.47	.50		
600	.25	.28	.31	.34	.37	.39	.41	.43	.47	.51			
800	.27	.30	.33	.36	.39	.42	.44	.46	.50				
1000	.28	.32	.36	.39	.41	.44	.47	.49					
1200	.30	.34	.37	.41	.43	.46	.49	.51					
1400	.31	.35	.38	.42	.45	.48	.51						
1600	.31	.36	.40	.43	.47	.50							
1800	.32	.37	.41	.45	.48	.51							
2000	.33	.37	.42	.46	.49								
Alfalfa and Grass n = .15													
200	.23	.26	.29	.32	.34	.36	.38	.40	.44	.47	.50	.53	.56
300	.25	.29	.32	.35	.38	.40	.42	.44	.48	.52	.55	.58	.61
400	.27	.31	.35	.38	.41	.43	.45	.48	.52	.56	.59		
600	.30	.34	.38	.41	.44	.47	.49	.52	.57	.61			
800	.32	.36	.40	.44	.47	.50	.53	.56	.61				
1000	.34	.39	.43	.47	.50	.53	.56	.59					
1200	.36	.41	.45	.49	.52	.55	.58	.61					
1400	.37	.42	.46	.50	.54	.57	.60						
1600	.38	.43	.48	.52	.56	.59							
1800	.39	.44	.49	.53	.57	.61							
2000	.40	.45	.50	.55	.59								

Example of Use:

Crop alfalfa. From Table 6.1
Length was 1200 feet. q = .005 cfs per foot width per 100' length.
The "Q" per foot width of Q/W = $.005 \times \frac{1200}{100} = .005 \times 12 = .06$

From table above, Q/W of .06 for 1200 feet length gives flow depth of approximately .49 foot.

Table 6.3

Unit Streams, Time of Application

and Design Efficiencies for Graded Border Irrigation

Irrigation Design Group	Grade Ft/Ft	2.0" Net Application			3.0" Net Application			4.0" Net Application			5.0" Net Application		
		Unit q	T_A	Eff.	Unit q	T_A	Eff.	Unit q	T_A	Eff.	Unit q	T_A	Eff.
3 and 4 (0.3)	.001	.0023	190	65	.0017	380	65	.00145	590	65	.0013	830	65
	.002	.0023	200	60	.0018	390	60	.00170	600	55	*.0016	840	50
	.004	.0025	205	55	*.0021	400	50	*.00185	600	50	*.0016	840	50
	.007	.0027	205	50	*.0021	400	50	*.00185	600	50	-	-	-
5 and 6 (0.5)	.001	.0038	105	70	.0030	200	70	.0026	310	70	.0023	430	70
	.002	.0038	110	65	.0030	210	65	.0026	330	65	.0024	450	65
	.004	.0038	120	60	.0032	220	60	.0028	330	60	.0026	450	60
	.007	.0038	120	60	.0035	220	55	*.0032	330	55	*.0028	450	55
	.015	*.0044	120	55	*.0038	220	50	*.0034	330	50	*.0031	450	50
7 and 8 (1.0)	.001	.0082	49	70	.0063	90	75	.0054	140	75	.0048	195	75
	.002	.0079	54	65	.0062	95	70	.0053	150	70	.0048	200	75
	.004	.0076	60	60	.0062	105	65	.0053	160	65	.0048	205	70
	.007	.0076	60	60	.0062	105	65	.0053	160	65	.0050	215	65
	.015	.0076	65	55	.0062	110	60	.0053	170	60	.0052	220	60
	.030	.0076	65	55	*.0062	110	60	*.0057	170	55	*.0063	220	50
9 and 10 (1.5)	.001	.0121	33	70	.0095	60	75	.0079	90	80	.0072	120	80
	.002	.0120	36	65	.0094	64	70	.0078	95	75	.0071	130	75
	.004	.0119	39	60	.0093	69	65	.0078	105	70	.0071	140	70
	.007	.0117	41	60	.0093	69	65	.0078	105	70	.0071	145	70
	.015	.0117	43	55	.0093	73	60	.0078	110	65	.0071	150	65
	.030	.0117	43	55	.0093	73	60	.0084	110	60	.0077	150	60

Example of Use: Irrigation Group 5
4.0"
02 or .20 ft. per 100'
cfs
s and eff. = 65%
ng of border stream

T_A = minutes to apply water
Unit q = stream size per foot width for 100' border length in cfs
Eff. = design efficiency in %

Table 6.4

Maximum Length of Run for Graded Border Irrigation

For Close Grown Crops

Slope Groups	0.05-0.14	0.15-0.25	0.26-0.55	0.56-1.0	1.1-2.0	1.1-2.0	2.1-4.0
Design Slope	0.1%	0.2%	0.4%	0.7%	1.5%	1.5%	3.0%
Stream Q/W	.075	.075	.075	.075	.044*	.075	.053*
Unit Stream "q"						Sod Only	
0.013	580	580	580	580	340	580	410
0.012	620	620	620	620	370	620	440
0.011	680	680	680	680	400	680	480
0.010	750	750	750	750	440	750	530
0.009	830	830	830	830	500	830	590
0.008	940	940	940	940	550	940	660
0.007	1070	1070	1070	1070	630	1070	760
0.006	1250	1250	1250	1250	730	1250	880
0.005	1500	1500	1500	1500	880	1500	1060
0.0045	1670	1670	1670	1670	980	1670	
0.0040	1870	1870	1870	1870	-	-	
0.0035	2140	2140	2140	2140	-	-	
0.0030	2460	2460	2460				
0.0027	2600	2600	2600				
0.0020	2600	2600	-				

Unit stream too small to provide adequate spread.

*Maximum non-erosive stream $Q/W = 0.06(100S_o)^{-.75}$
$= 0.12(100S_o)^{-.75}$ for sod

Table stops at .075 Q/W because of practical stream sizes.

Example of Use: Unit stream from example on previous page q = .0026
Grade of border .002 or 0.2 percent
Then maximum length = 2600 feet

Table 6.5

Minimum and Maximum Stream Sizes

For Graded Borders

Minimum Unit Stream "q" (cfs)		Grade of Border Ft/100 Ft.	Maximum Stream Q/W (cfs/Ft. Width)	
Small Gr. n = 0.10	Alfalfa n = 0.15		Alfalfa and Small Grain	Sod
.0019	.0013	0.10	0.075	0.075
.0027	.0018	0.20	0.075	0.075
.0038	.0026	0.40	0.075	0.075
.0052	.0035	0.70	0.075	0.075
.0073	.0049	1.50	0.044	0.075
.0097	.0065	3.00		0.053

Maximum stream limited to 0.075 for practical operation of border systems.

$$\text{Minimum Unit Stream "q"} = \frac{0.006\ (S^{0.5})}{n}$$

$$\text{Maximum Stream per foot width } Q/W = 0.06(100S_o)^{-0.75}$$

Table 6.6

Flow Depths for Various Irrigation Streams (Feet)

Irrigation Stream "Q/W"	Grade - Feet per 100 ft. and (n) values										
	0.10		0.20		0.40		0.70		1.50		3.00
	.15	.10	.15	.10	.15	.10	.15	.10	.15	.10	.15
.01	.13	.10	.10	.08	.08	.07	.07	.05	.06	.04	.05
.02	.19	.15	.16	.12	.13	.10	.10	.08	.08	.06	.06
.03	.24	.19	.20	.15	.16	.13	.13	.11	.11	.08	.08
.04	.29	.23	.24	.18	.19	.15	.16	.13	.13	.10	.10
.05	.33	.26	.27	.21	.22	.17	.18	.15	.15	.11	.12
.06	.37	.29	.30	.24	.24	.19	.20	.16	.17	-	-
.07	.40	.32	.33	.26	.27	.21	.22	.17	.18	-	-
.08	.43	.35	.36	.28	.29	.23	.24	.19	-	-	-
.09	.47	.38	.38	.30	.31	.25	Erosive Irrigation Streams				
.10	.50	.40	.41	.33	.33	.27					
.12		.45	.46	.37	-	-					

$$\text{Flow depth "d"} = \frac{(Q/W)^{0.6}}{\left(\frac{1.486}{n}\right)^{0.6}(S_o)^{0.3}}$$

Example: Crop is alfalfa with "n" value of .15
From previous page, maximum length = 2600 feet
q = .0026, grade = .20 feet/100 feet
Then Q/W = .0026 x 26 = .0676
Read from above table. Flow depth approximately .32 foot

Table 6.7

Time in Minutes Required to Apply

1.0" of Water Using Various Size Unit Streams

Unit Streams	.000	.0001	.0002	.0003	.0004	.0005	.0006	.0007	.0008	.0009
.001	138.9	126.2	115.7	106.8	99.3	92.7	86.9	81.8	77.2	73.2
.002	69.4	66.2	63.2	60.4	57.9	55.6	53.4	51.5	49.7	47.9
.003	46.3	44.8	43.4	42.1	40.9	39.7	38.6	37.5	36.5	35.6
.004	34.7	33.9	33.1	32.3	31.6	30.9	30.2	29.6	29.0	28.4
.005	27.8	27.3	26.8	26.3	25.8	25.3	24.8	24.4	24.0	23.6
.006	23.2	22.8	22.4	22.0	21.7	21.4	21.1	20.8	20.4	20.1
.007	19.8	19.6	19.3	19.1	18.8	18.5	18.3	18.1	17.8	17.6
.008	17.4	17.2	17.0	16.8	16.6	16.4	16.2	16.0	15.8	15.6
.009	15.4	15.3	15.1	14.9	14.8	14.6	14.5	14.3	14.2	14.0
.010	13.9	13.8	13.6	13.5	13.4	13.2	13.1	13.0	12.8	12.7
.011	12.6	12.5	12.4	12.3	12.2	12.1	12.0	11.9	11.8	11.7
.012	11.6	11.5	11.4	11.3	11.2	11.1	11.0	10.9	10.8	10.8
.013	10.7	10.6	10.5	10.4	10.3	10.2	10.2	10.1	10.0	10.0
.014	9.9	9.9	9.8	9.8	9.7	9.6	9.5	9.5	9.4	9.3
.015	9.3	9.2	9.2	9.1	9.0	9.0	8.9	8.9	8.8	8.7
.016	8.7	8.6	8.6	8.5	8.5	8.4	8.4	8.3	8.3	8.2
.017	8.2	8.1	8.1	8.0	8.0	7.9	7.9	7.8	7.8	7.8
.018	7.7	7.7	7.6	7.6	7.6	7.5	7.5	7.4	7.4	7.4
.019	7.3	7.3	7.2	7.2	7.2	7.1	7.1	7.1	7.0	7.0
.020	6.9	6.9	6.9	6.8	6.8	6.8	6.7	6.7	6.7	6.6

$$T = \frac{.1389d}{q}$$

Example of Use: Unit stream .0043. Gross depth of application is 4.8".
Then time to apply = 4.8 x 32.3 = 155 minutes.

From previous example:

Unit stream = .0026
Net application is 4.0"
Efficiency = 65%
Then gross application $= \frac{4.0}{.65} = 6.15$

From table, minutes to apply 1.0" with unit stream of .0026 is 53.4 minutes. 53.4 minutes per inch and 6.15 inches = 53.4 x 6.15 = 328 minutes.

Table 6.8

Opportunity Time (T_o) in Hours, Average Intake Rate (I_a) in Inches per Hour and Lateral Spread (LS) in Inches, for Net Intake with Varying Values of "g"

Intake Family	Value of "g"	Net Application -- Inches (F_n)																	
		2.0"			2.5"			3.0"			3.5"			4.0"			4.5"		
		T_o	I_a	LS	T_o	I_a	LS	T_o	I_a	LS	T_o	I_a	LS	T_o	I_a	LS	T_o	I_a	LS
0.3	0.90	4.9	.41	17	6.6	.38	19	8.5	.35	22	10.6	.33	25	12.8	.31	28	16.5	.29	31
	0.80	5.8	.34	18	7.8	.32	21	10.0	.30	24	12.5	.28	27	15.0	.27	30	17.8	.25	39
	*0.75	6.4	.31	19	8.6	.29	22	11.1	.27	25	13.8	.25	28	16.9	.24	31	19.6	.23	33
	0.70	7.0	.29	20	9.5	.26	24	12.3	.24	27	15.2	.23	30	18.3	.22	33	21.5	.27	35
	0.60	8.7	.23	22	11.7	.21	27	15.0	.20	30	18.7	.19	33	22.7	.18	36	26.8	.17	39
0.5	0.80	3.2	.63	14	4.2	.60	17	5.3	.56	19	6.5	.54	21	7.7	.52	23	9.0	.50	24
	0.70	3.8	.53	16	5.0	.50	19	6.3	.47	21	7.7	.45	23	9.2	.43	25	10.8	.42	27
	*0.65	4.2	.58	17	5.5	.45	20	7.0	.43	22	8.5	.41	24	10.2	.39	26	11.9	.38	28
	0.60	4.6	.44	18	6.1	.41	21	7.7	.39	23	9.4	.37	26	11.3	.35	28	13.2	.34	30
	0.50	5.8	.35	20	7.7	.33	23	9.8	.31	26	12.2	.29	28	14.3	.28	31	16.7	.27	33
0.75	0.75	2.4	.84	14	3.1	.81	16	3.9	.77	18	4.8	.73	20	5.8	.69	21	6.8	.66	23
	0.65	2.9	.70	15	3.8	.66	17	4.8	.63	19	5.9	.60	21	7.0	.58	23	8.1	.56	25
	*0.60	3.2	.63	16	4.3	.58	18	5.4	.56	20	6.5	.54	22	7.7	.52	24	9.0	.50	26
	0.55	3.5	.57	17	4.7	.53	19	6.0	.50	21	7.3	.48	24	8.7	.46	26	10.1	.45	28
	0.45	4.5	.45	19	6.0	.42	21	7.6	.40	23	9.3	.38	26	11.1	.36	29	13.0	.35	32
1.0	0.70	1.8	1.10	12	2.4	1.05	14	3.0	1.00	16	3.7	.96	18	4.3	.92	19	5.0	.90	20
	0.60	2.3	.90	14	2.9	.85	16	3.7	.82	18	4.5	.78	20	5.3	.75	21	6.2	.73	22
	*0.55	2.6	.81	15	3.3	.76	17	4.2	.73	19	5.2	.70	21	6.0	.67	22	6.9	.65	23
	0.50	2.8	.72	16	3.7	.68	18	4.7	.65	20	5.7	.62	22	6.7	.60	23	7.8	.58	25
	0.40	3.7	.54	18	4.9	.51	20	6.2	.49	23	7.5	.47	25	8.9	.45	27	10.2	.44	29
1.5	0.65	1.4	1.45	12	1.8	1.38	14	2.3	1.32	15	2.8	1.27	16	3.3	1.22	18			
	0.55	1.7	1.18	13	2.2	1.13	15	2.8	1.08	17	3.4	1.04	18	4.0	1.00	20			
	*0.50	1.9	1.06	14	2.5	1.00	16	3.1	0.96	18	3.8	.92	19	4.5	.89	21			
	0.45	2.2	.93	15	2.9	.88	18	3.6	.84	20	4.4	.81	21	5.2	.78	23			
	0.35	3.1	.68	17	3.9	.64	20	4.9	.61	22	6.1	.59	24	7.2	.59	26			
2.0	0.65	1.1	1.92	11	1.4	1.85	13	1.7	1.70	14	2.1	1.65	15						
	0.55	1.3	1.56	12	1.7	1.50	14	2.1	1.45	16	2.6	1.38	17						
	*0.50	1.5	1.38	13	1.9	1.31	15	2.4	1.26	17	2.9	1.21	18						
	0.45	1.7	1.21	14	2.2	1.16	16	2.7	1.13	18	3.3	1.10	20						
	0.35	2.3	.89	16	2.9	.84	18	3.6	.80	20	4.4	.78	22						

$F_n = gat^b$ $\quad LS = \frac{4}{3}\frac{d}{y}t^{0.5}$ $\quad$ *Use for general design

Table 6.9

Initial Application Rate in g.p.m. per 100 Feet

With Varying Values of "g" when $(W_1 + \frac{4}{3}\frac{dt^{0.5}}{\bar{y}}) \geq$ Furrow Spacing

Intake Family	Value of "g"	Net Application -- Inches																	
		2.0"			2.5"			3.0"			3.5"			4.0"			4.5"		
		30	36	40	30	36	40	30	36	40	30	36	40	30	36	40	30	36	40
0.3	0.90	1.6	1.8	2.1	1.5	1.7	2.0	1.4	1.6	1.9	1.3	1.5	1.8	1.2	1.4	1.7	1.2	1.4	1.6
	0.80	1.3	1.6	1.8	1.2	1.5	1.7	1.2	1.4	1.6	1.1	1.3	1.5	1.1	1.3	1.4	1.0	1.2	1.3
	*0.75	1.2	1.5	1.7	1.1	1.4	1.5	1.1	1.3	1.4	1.0	1.2	1.3	0.9	1.1	1.2	0.9	1.1	1.2
	0.70	1.1	1.4	1.5	1.0	1.3	1.4	1.0	1.2	1.3	0.9	1.1	1.2	0.8	1.0	1.1	0.8	0.9	1.0
	0.60	0.9	1.1	1.2	0.8	1.0	1.1	0.8	0.9	1.0	0.7	0.8	0.9	0.7	0.8	0.9	0.6	0.7	0.8
0.5	0.80	2.5	3.0	3.3	2.3	2.8	3.1	2.2	2.6	2.9	2.1	2.5	2.8	2.0	2.4	2.7	1.9	2.3	2.6
	0.70	2.1	2.5	2.8	2.0	2.3	2.6	1.9	2.2	2.4	1.8	2.1	2.3	1.7	2.0	2.2	1.5	1.9	2.1
	*0.65	1.9	2.3	2.6	1.8	2.1	2.4	1.7	2.0	2.2	1.6	1.9	2.1	1.5	1.8	2.0	1.4	1.7	1.9
	0.60	1.7	2.1	2.3	1.6	1.9	2.1	1.5	1.8	2.0	1.4	1.7	1.9	1.3	1.6	1.8	1.2	1.5	1.7
	0.50	1.4	1.6	1.8	1.3	1.5	1.7	1.2	1.5	1.7	1.1	1.4	1.6	1.1	1.3	1.5	1.0	1.2	1.4
0.75	0.75	3.4	4.1	4.4	3.2	3.8	4.1	3.0	3.6	3.9	2.9	3.4	3.7	2.8	3.2	3.5	2.7	3.1	3.4
	0.65	2.8	3.4	3.7	2.6	3.2	3.5	2.5	2.0	3.3	2.4	2.8	3.1	2.3	2.7	3.0	2.2	2.6	2.9
	*0.60	2.5	3.0	3.3	2.3	2.8	3.1	2.2	2.6	2.9	2.1	2.5	2.8	2.0	2.4	2.7	1.9	2.3	2.6
	0.55	2.2	2.7	3.0	2.1	2.5	2.8	2.0	2.4	2.7	1.9	2.3	2.6	1.8	2.2	2.5	1.7	2.1	2.4
	0.45	1.7	2.1	2.3	1.6	2.0	2.2	1.5	1.9	2.1	1.4	1.8	2.0	1.3	1.7	1.9	1.2	1.6	1.8
1.0	0.70	4.3	5.2	5.7	4.1	4.9	5.5	3.9	4.7	5.2	3.7	4.5	5.0	3.6	4.3	4.8	3.5	4.2	4.7
	0.60	3.5	4.2	4.7	3.3	4.4	4.5	3.2	3.8	4.3	3.0	3.7	4.1	2.9	3.5	3.9	2.8	3.4	3.8
	*0.55	3.2	3.8	4.3	3.0	3.6	4.0	2.9	3.4	3.8	2.7	3.3	3.6	2.6	3.2	3.5	2.5	3.1	3.4
	0.50	2.8	3.4	3.8	2.6	3.2	3.6	2.5	3.0	3.4	2.4	2.9	3.2	2.3	2.8	3.1	2.2	2.7	3.0
	0.40	2.1	2.5	2.8	2.0	2.4	2.7	1.9	2.3	2.5	1.8	2.2	2.4	1.7	2.1	2.3	1.6	2.0	2.2
1.5	0.65	5.6	6.8	7.5	5.4	6.5	7.2	5.2	6.2	6.9	5.0	6.0	6.6	4.8	5.7	6.3			
	0.55	4.6	5.6	6.2	4.4	5.3	5.9	4.3	5.1	5.6	4.1	4.9	5.4	3.9	4.7	5.2			
	*0.50	4.1	5.0	5.5	3.9	4.7	5.2	3.7	4.5	5.0	3.6	4.3	4.8	3.5	4.2	4.6			
	0.45	3.6	4.4	4.8	3.4	4.2	4.6	3.3	4.0	4.4	3.1	3.8	4.2	3.0	3.7	4.1			
	0.35	2.7	3.2	3.6	2.5	3.0	3.4	2.4	2.9	3.2	2.3	2.8	3.1	2.2	2.7	3.0			
2.0	0.65	7.5	9.0	9.9	7.1	8.6	9.5	6.8	8.2	9.1	6.5	7.9	8.7						
	0.55	6.1	7.4	8.2	5.8	7.0	7.8	5.5	6.7	7.4	5.3	6.5	7.1						
	*0.50	5.4	6.5	7.2	5.2	6.2	6.8	5.0	5.9	6.5	4.8	5.7	6.3						
	0.45	4.8	5.7	6.4	4.6	5.4	6.1	4.4	5.2	5.8	4.2	5.0	5.6						
	0.35	3.5	4.2	4.7	3.3	4.0	4.5	3.2	3.8	4.3	3.1	3.7	4.1						

When $(W_1 + \frac{4}{3}\frac{dt^{0.5}}{\bar{y}}) < W_2$, Increase planned net application as needed to a maximum increase of 35% to obtain desired average application and determine appropriate average application rate and time.

Initial application "q" = 1.5 I_a where I_a is average intake gpm/100 feet

*Use for general design

Table 6.10

Top Width of Furrow Stream - Inches

Parabolic Furrows

n = .04

g.p.m. Q	Slope - Ft./Ft.				
	.0005	.001	.002	.004	.007
50	21	19	18	-	-
45	20	19	17	-	-
40	20	18	17	-	-
35	19	18	16	15	-
30	19	17	16	15	-
25	18	16	15	14	-
20	17	15	14	13	12
15	16	14	13	12	11
10	14	13	12	11	10

Top Width of Furrow Stream - Inches

B.W. = 0.5' SS = 2:1 n = .04

g.p.m. Q	Slope - Ft./Ft.				
	.0005	.001	.002	.004	.007
50	22	20	18	-	-
45	21	19	17	-	-
40	21	18	16	-	-
35	20	18	16	14	-
30	19	17	15	14	-
25	17	16	14	13	-
20	16	15	13	12	11
15	15	14	12	11	10
10	13	12	11	10	9

Table 6.11

Conversion of Intake Rate from Gallons per Minute per 100 Feet of Furrow to Inches Depth Over the Field

Intake Rate or Application Rate Per 100 Ft. of Furrow g.p.m.	Intake Rate - Inches per Hour for Following Furrow Spacings								
	20"	22"	30"	36"	40"	44"	48"	60"	72"
0.4	0.23	0.21	0.15	0.13	0.12	0.11	0.10	0.08	0.06
0.6	0.35	0.31	0.23	0.19	0.17	0.16	0.15	0.12	0.09
0.8	0.46	0.42	0.31	0.26	0.23	0.21	0.19	0.15	0.13
1.0	0.58	0.52	0.38	0.32	0.29	0.26	0.24	0.19	0.16
1.2	0.69	0.63	0.46	0.39	0.35	0.32	0.29	0.23	0.19
1.4	0.81	0.73	0.54	0.45	0.40	0.37	0.34	0.27	0.22
1.6	0.92	0.84	0.62	0.51	0.46	0.42	0.39	0.31	0.26
1.8	1.05	0.94	0.70	0.58	0.52	0.47	0.44	0.35	0.29
2.0	1.16	1.05	0.77	0.64	0.58	0.53	0.48	0.39	0.32
2.2	1.27	1.15	0.85	0.71	0.64	0.58	0.53	0.42	0.35
2.4	1.39	1.26	0.92	0.77	0.69	0.63	0.58	0.46	0.38
2.6	1.50	1.36	1.00	0.83	0.75	0.68	0.63	0.50	0.41
2.8	1.62	1.47	1.08	0.90	0.81	0.74	0.68	0.54	0.45
3.0	1.73	1.57	1.16	0.96	0.87	0.79	0.73	0.58	0.48
3.2	1.85	1.68	1.23	1.03	0.93	0.84	0.77	0.62	0.51
3.4	1.97	1.78	1.31	1.09	0.98	0.89	0.82	0.66	0.54
3.6	2.08	1.89	1.39	1.15	1.04	0.95	0.87	0.69	0.57
3.8	2.20	1.99	1.47	1.22	1.10	1.00	0.92	0.73	0.61
4.0	2.31	2.10	1.54	1.28	1.16	1.05	0.97	0.77	0.64
4.2	2.43	2.20	1.62	1.35	1.22	1.10	1.02	0.81	0.67
4.4	2.54	2.31	1.70	1.41	1.27	1.16	1.06	0.85	0.70
4.6	2.66	2.41	1.77	1.47	1.33	1.21	1.11	0.89	0.73
4.8	2.77	2.52	1.85	1.54	1.39	1.26	1.16	0.93	0.77
5.0	2.89	2.62	1.92	1.60	1.45	1.31	1.21	0.96	0.80
5.5	3.18	2.73	2.12	1.77	1.59	1.37	1.33	1.06	0.88
6.0	3.47	3.15	2.32	1.93	1.73	1.58	1.45	1.16	0.96
6.5	3.76	3.41	2.50	2.09	1.88	1.71	1.57	1.25	1.04
7.0	4.05	3.67	2.70	2.25	2.02	1.84	1.69	1.35	1.12
7.5	4.34	3.94	2.89	2.41	2.17	1.97	1.82	1.45	1.20
8.0	4.62	4.20	3.09	2.57	2.31	2.10	1.94	1.54	1.28

$$\text{Intake rate} = \text{g.p.m. per 100' row} \left(\frac{11.55}{\text{Furrow spacing (in.)}}\right)$$

Example of Use: Application rate = 1.9 g.p.m. per 100'. Furrows are spaced 36", then application rate in inches per hour is between 0.58 and 0.64 or 0.61 inch per hour.

Table 6.12

Selection of Schedules for Furrow Irrigation

Re-Use Procedure		Cut-back Procedure	
1/ T_A (Hrs.)	Operating Schedule	Needed T_o Hrs.	Operating Schedule
1.7 to 2.3	2.0	3.8 to 4.6	2-2-4
2.4 to 3.3	3.0	4.7 to 5.7	2.5-2.5-5
3.4 to 4.3	4.0	5.8 to 7.0	3-3-6
4.4 to 5.3	5.0	7.1 to 9.2	4-4-8
5.4 to 6.6	6.0	9.3 to 11.4	5-5-10
6.7 to 8.7	8.0	11.5 to 14.4	6-6-12
8.8 to 10.9	10.0	14.5 to 18.7	8-8-16
11.0 to 13.2	12.0	18.8 to 22.9	10-10-20
13.3 to 17.5	16.0	23.0 to 28.0	12-12-24
17.6 to 21.4	20.0		
21.5 to 26.0	24.0		

1/ $T_A = 1.18\ T_o$ (approximately)

Example: Soil intake family is 0.3. Net application is 3.0". From Table 6.8 T_o = 11.1 hrs. T_A would be (1.18)(11.1) = 13.1 hrs. Then from above table, time to apply water for re-use system is 12 hours and for cut-back system 5-5-10 hour schedule.

Table 6.13

Approximate Flow of Various Size Siphon Tubes
(Gallons per Minute)

Tube Size	Head Causing Flow Through Tube*				
	2"	3"	4"	6"	9"
1/2"	1.3	1.6	1.8	2.1	2.7
3/4"	3	4	5	6	7
1"	5	6	7	9	11
1¼"	8	10	12	15	18
1½"	13	16	18	24	28
2"	21	27	32	41	50
2½"	32	40	48	54	65
3"	46	57	65	82	100
4"	86	106	122	153	200

*Head is the difference in elevation of water in the supply ditch and center of discharge end of tube or outlet water surface if discharge end is submerged.

Table 6.14

Clock Time for Change of Furrow Streams

Operation Schedules--Time to Change--Days to Complete Cycle - Number Sets per Cycle							
12-12-24	10-10-20	8-8-16	6-6-12**	5-5-10	4-4-8	3-3-6	2-2-4
6:00 A.M.	6:00 A.M.	6:00 A.M.	6:00 A.M.	6:00 A.M.	6:00 A.M.	6:00 A.M.	6:00 A.M.
6:00 P.M.	4:00 P.M.	2:00 P.M.	12:00 P.M.	11:00 A.M.	10:00 A.M.	9:00 A.M.	8:00 A.M.
6:00 A.M.	2:00 A.M.*	10:00 P.M.*	6:00 P.M.	4:00 P.M.	2:00 P.M.	12:00 P.M.	10:00 A.M.
Repeat	10:00 P.M.	2:00 P.M.	Repeat	Repeat	10:00 P.M.*	6:00 P.M.	2:00 P.M.
2 days	8:00 A.M.	10:00 P.M.*	1 day	(Automatic pump shut-off at 2:00 A.M.)	2:00 A.M.*	9:00 P.M.*	4:00 P.M.
1 set	6:00 P.M.	6:00 A.M.	1 set		6:00 A.M.	12:00 P.M.*	6:00 P.M.
	2:00 P.M.	10:00 P.M.*			2:00 P.M.	Repeat	10:00 P.M.*
	12:00 A.M.*	6:00 A.M.		1 day 1 set	6:00 P.M.	1 day	12:00 P.M.*
	10:00 A.M. 6:00 P.M.	2:00 P.M.			10:00 P.M.*	2 sets	2:00 A.M.*
	Repeat	Repeat			Repeat		Repeat
	5 days	4 days			2 days		1 day
	3 sets	3 sets			3 sets		3 sets

*Indicates night operation

6:00 A.M. selected as starting time. Change accordingly for other times.

**Example: A 6-6-12 hour schedule means water applied to even-numbered rows for 6 hours, then to odd-numbered rows for 6 hours, then to all rows for 12 hours.

Table 6.15

Acre Feet of Water Pumped in T. Hours

T. Hours Pumping	Pump Discharge - Gallons per Minute											
	200	300	400	500	600	700	800	900	1000	1100	1200	1300
6	0.22	0.33	0.44	0.55	0.66	0.77	0.88	0.99	1.10	1.22	1.33	1.44
8	0.29	0.44	0.59	0.74	0.88	1.03	1.18	1.33	1.47	1.62	1.77	1.91
10	0.37	0.55	0.74	0.92	1.10	1.29	1.47	1.66	1.84	2.03	2.21	2.39
12	0.44	0.66	0.88	1.11	1.33	1.55	1.77	1.99	2.21	2.43	2.65	2.87
14	0.52	0.77	1.03	1.29	1.55	1.80	2.06	2.32	2.58	2.84	3.09	3.35
16	0.59	0.88	1.18	1.47	1.77	2.06	2.36	2.65	2.95	3.24	3.53	3.83
18	0.66	0.99	1.33	1.66	1.99	2.32	2.65	2.98	3.31	3.65	3.98	4.31
20	0.74	1.10	1.47	1.84	2.21	2.58	2.95	3.31	3.68	4.05	4.42	4.79
22	0.81	1.22	1.62	2.03	2.43	2.84	3.24	3.65	4.05	4.46	4.86	5.27
24	0.88	1.33	1.77	2.21	2.65	3.09	3.53	3.98	4.42	4.86	5.30	5.74
26	0.96	1.44	1.91	2.39	2.87	3.35	3.83	4.31	4.79	5.27	5.74	6.22
28	1.03	1.55	2.06	2.58	3.09	3.61	4.12	4.64	5.15	5.67	6.19	6.70
30	1.10	1.66	2.21	2.76	3.31	3.87	4.42	4.97	5.52	6.08	6.63	7.18
32	1.18	1.77	2.36	2.95	3.53	4.12	4.71	5.30	5.89	6.48	7.07	7.66
34	1.25	1.88	2.50	3.13	3.76	4.38	5.01	5.63	6.26	6.89	7.51	8.14
36	1.33	1.99	2.65	3.31	3.98	4.64	5.30	5.96	6.63	7.29	7.95	8.62
38	1.40	2.10	2.80	3.50	4.20	4.90	5.60	6.30	7.00	7.70	8.39	9.09
40	1.47	2.21	2.95	3.68	4.42	5.15	5.89	6.63	7.36	8.10	8.84	9.57
45	1.66	2.49	3.31	4.14	4.97	5.80	6.63	7.46	8.28	9.11	9.94	10.77
50	1.84	2.76	3.68	4.60	5.52	6.44	7.36	8.28	9.21	10.12	11.05	11.97

PART 7 - IRRIGATION APPLICATION

A. Adjusting to Fit Conditions

An irrigation guide does not cover all of the irrigation features for a given area and questions will arise as to how the guide can be used in these cases. In some instances the information will have to be obtained from other sources. In the guide the data given is of a broad nature and it can be applied to other than the specific included conditions.

1. Irrigation of Other Crops - Sorghum or sudangrass planted by drilling could be irrigated by borders like small grain but irrigation would be timed to suit the crop.

   Grass for seed production is frequently grown in rows but has not been included in the design sheets. Consumptive use values would be similar to grass pasture and intake rates that apply for furrow irrigation would be approximately correct.

2. Field Slopes Exceeding Those Shown in the Guide - Furrow grades may be reduced by cross-slope or contour furrow irrigation. When this is done, the figures in the guide which apply are those from the slope group which matches the furrow grade. Cross-slope furrow channels must be maintained large enough to carry runoff and irrigation flows to avoid overtopping.

   Borders can also be run across the slope with the side fall removed in the leveling process. Again the criteria that applies is that listed for the border grade. Bench leveling can frequently be used on slopes up to 5 percent to reduce the irrigation slope to acceptable design slope for either border or furrow irrigation.

3. Practical Water Application Schedules - The guide gives specific hours and hour fractions for application of the irrigation water. The time shown is the proper time of application "T_A" for all methods except furrow, cutback. For this method, the time listed is the needed opportunity time "T_O." For normal use farm schedules these times should be converted to a practical operating schedule as shown in Table 6.12, page 6-13.

As an example, assume that the cutback furrow method is to be used and the time needed (T_o) is 8.8 hours. Then from Table 6.12 the schedule shown is 4-4-8. Also assume that 60 rows are to be irrigated each set. The schedule means that water will be turned down 30 alternate furrows for 4 hours at the initial stream rate. At the end of the first 4 hour period the same amount of water would then be turned down the other 30 furrows. At the end of the second 4 hour period the amount of water turned down each row would be one-half the initial stream and all 60 furrows would be irrigated for a period of 8 hours.

For other methods of application the time shown is the needed application time "T_A." This should also be adjusted. Assume that "T" is shown in the guide as 9.5 hours. From Table 6.12 the adjusted time would be 10 hours.

4. Adjusting Guide Data to Fit Field Conditions - Soil intake rates may vary greatly within an irrigation season or from season to season. An irrigation guide is valuable only in giving general guidance for layout and operation of an irrigation system. The physical layout can be installed in accordance with the guide and operational adjustments then made for differences in intake rates and net application depths.

   The guide gives maximum length of run for surface irrigation methods. Fields frequently are of dimensions that do not fit these lengths. The guide, however, gives unit stream values for all gravity irrigation cases so any length of run can be adjusted within the maximum allowable to fit the field. Other irrigation control features such as net application, furrow stream and border width can be adjusted within the stated maximum to fit the field conditions.

B. Irrigation System Design and Water Management

Irrigation usually requires a high degree of management. Soil and topographic characteristics influence irrigation water application. Growth habits of crops, climatic conditions and quality of water available must be carefully considered. These and other factors are reflected in the values tabulated in the irrigation design guide sheets, pages 4-15 through 4-41.

Table 7.1, page 7-9, is an example of an irrigation system design. The actual design is made using various criteria from different sections of the guide. The design information is then listed on the design sheet which is Form KS-EN-216 (Rev.).

1. <u>Furrow or Corrugation Irrigation</u> - Table 7.1 is filled out as follows after determining the available water in gallons per minute and cubic feet per second. (Available water is found by subtracting any conveyance losses between the main water source and the field being irrigated.):

   (a) <u>Field No. 1</u>.

      (1) List the field number (1), area in acres (80), and the soil (Richfield silt loam).

      (2) Select the design group (3) and the intake family (0.3) of the soil from page 3-9. List the crop (corn) to be grown.

      (3) With a design slope of 0.4% (Slope Group 0.26 to 0.55%) refer to the design guide sheets on page 4-18. For corn, Column 1, find the net moisture to be replaced (3.5 in.), Column 3, with a reuse system and a furrow spacing of 30 in., Column 7.

      (4) Determine the length of run. In this example, it is 2,600 ft., Column 8; maximum furrow stream size of 26 g.p.m., Column 5; and the unit stream (1 g.p.m./100 ft. of length), Column 6.

      (5) Divide the available Q (1,200 g.p.m.) by the maximum furrow stream (26 g.p.m.) to find the number of rows per set (46).

      (6) Gross water used in applying 3.5 in. of net moisture is 4.1 in., Column 10, or 3.5 in. divided by the estimated field efficiency of 85%, Column 9, times 100.

      (7) Time to reach the end of row should be 20% of the total time (16.3 hrs.), Column 11, or 3.3 hrs.

      (8) Total time required is 16.3 hrs., Column 11. Find T_O (opportunity time), with "g" = 0.75 from Table 6.8, equals 13.8 hrs. T_A (Time of Application) = 1.18 T_O (approximately) = 1.18 x 13.8 = 16.3 hrs. Refer to Table 6.12, page 6-13, for a reuse procedure with T_A = 16.3 hrs. Use an operating schedule = 16.0 hrs.

(b) Field No. 2 - (Available water the same as Field No. 1)

(1) List field number (2), area in acres (80), and the soil (Dalhart fine sandy loam).

(2) Select the design group (7) and the intake family (1.0) of the soil from page 3-13. List the crop (sorghum) to be grown.

(3) With a design slope of 0.2% (Slope Group 0.15 to 0.25%), refer to the design guide sheets on page 4-29. For sorghum, Column 1, find the net moisture to be replaced (3.0 in.), Column 3, using a cutback head method of irrigation and a furrow spacing of 40 in., Column 7.

(4) Determine the length of run. In this example, 1,300 ft. - not 1,430 ft. as shown in the guide, Column 9. List the maximum furrow stream of 50 g.p.m., Column 5. However, due to the shorter length of run, the initial furrow stream will be the unit stream (3.5 g.p.m./100 ft.), Column 6, times 13 hundreds of feet, or 46 g.p.m. The cutback furrow stream will be one-half of the initial furrow stream, or 23 g.p.m.

(5) Divide the available Q (1,200 g.p.m.) by the initial furrow stream (46 g.p.m.) to find the number of rows for the initial set (26).

(6) Gross water used in applying 3.0 in. net moisture is 4.3 in., Column 10, or 3.0 in. divided by the estimated field efficiency (70%), Column 9, times 100.

(7) For irrigation times, refer to Table 6.8, page 6-9, for 1.0 intake family and a "g" of 0.55 read T_O = 4.2 hrs. which is the opportunity time for a 3.0 in. net application. T_A (application time) = 1.18 T_O = 1.18 x 4.2 = 5.0 hrs. Time to reach the end of the row = 20% x 5.0 ÷ 100 = 1.0 hr.

(8) Refer to Table 6.12, page 6-13, with T_O = 4.2 hrs. Using the cutback procedure, the operating schedule would equal 2-2-4, or 2 hrs. initial, 2 hrs. cutback, total of 4 hrs./set.

2. Border or Basin Irrigation - Reference the right side of Table 7.1, page 7-9, for this method of irrigation. Determine the available water the same as for Field Nos. 1 and 2.

(a) Field No. 3

(1) List the field number (3), area in acres (60), and the soil (Harney silt loam).

(2) Select the design group (3) and the intake family (0.3) from page 3-9. List the crop (alfalfa) to be grown.

(3) With a design slope of 0.4% (Slope Group 0.26 to 0.55%) refer to the design guide sheets on page 4-18. For alfalfa, Column 1, find the net moisture to be replaced (4.0 in.), Column 3, using the border method of irrigation.

(4) Determine the length of run. For this example, it would be 2,600 ft., Column 8. The unit stream q would be 0.0019 c.f.s./100 sq. ft., Column 6.

(5) Compute the c.f.s./ft. of width (Q/w) = Length of run in hundreds of feet (26) times the unit q (0.0019) = 0.0494 c.f.s./ft. of width.

(6) Divide the available Q (2.67 c.f.s.) by Q/w or L x q (0.0494) = 54 ft. which is the border width. For this example it would be optional to use either one border 54 ft. wide, or 2 borders 27 ft. wide. Column 7 shows a maximum permissible border width of 60 ft. For this example, however, two 27-ft. borders will be used.

(7) The border stream would be Q/w (0.0494) times 27 ft. wide, or 1.33 c.f.s. or 600 g.p.m./border.

(8) Find the flow depth of the border in Table 6.6, page 6-7, by interpolating between a Q/w of 0.04 and 0.05 for Q/w = 0.0494, a design grade of 0.4% and an "n" value of 0.15. d = 0.21 ft.

(9) Border height = d + 0.2 ft. = 0.41 ft.

(10) Find the estimated field efficiency of 50%, Column 9.

(11) The average time per set is 10 hrs., Column 11, or solve by multiplying 0.23 times the net application (4.0 in.) and divide by the product of the estimated field efficiency (50%) times the unit stream q (0.0019 c.f.s./ 100 sq. ft.) which equals 9.7 or 10.0 hrs.

(b) Field No. 4

(1) List the field number (4), area in acres (100), and the soil (Naron fine sandy loam).

(2) Select the design group (7) and the intake family (1.0) from page 3-13. List the crop (grass) to be grown.

(3) With a design slope of 0.7% (Slope Group 0.56 to 1.0%), refer to the design guide sheets on page 4-30. For grass, Column 1, find the net moisture to be replaced (3.0 in.), Column 3, using the border method of irrigation.

(4) Determine the length of run. For this example it would be 1,200 ft., Column 8, (round to even 100's). The unit stream q would be 0.0062 c.f.s./100 sq. ft., Column 6.

(5) Compute the c.f.s./ft. of width (Q/w) = Length of run in hundreds of feet (12) times the unit q (0.0062) = 0.0744 c.f.s./ft. of width.

(6) Divide the available Q (2.67 c.f.s.) by Q/w or L x q (0.0744) = 36 ft. which is the border width. Maximum permissible border width is 50 ft., Column 7, so this width is O.K.

(7) The border stream would be Q/w (0.0744) times 36 ft. wide, or 2.67 c.f.s. or 1,200 g.p.m. for each border.

(8) Find the flow depth of the border in Table 6.3, page 6-7, by interpolating between a Q/w of 0.07 and 0.08 for Q/w = 0.0744, a design grade of 0.7% and an "n" value of 0.15. d = 0.23 ft.

(9) Border height = d + 0.2 ft. = 0.43 ft.

(10) Find the estimated field efficiency of 65%, Column 9.

(11) Compute the average time per set by multiplying 0.23 times the net application (3.0 in.) and divide by the product of the estimated field efficiency (65%) times the unit stream q (0.0062 c.f.s./100 sq. ft.) which equals 1.7 hrs.

3. <u>Checking Water Supply Adequacy</u> - Whether a water supply is adequate depends on which method or the intensity of irrigation planned. Different methods are explained in the Procedure Guide for Irrigation Land Development on page 1-4. Monthly NIR (Net Irrigation Requirement) values are discussed on page 2-11, and Peak Consumptive Use on page 2-25.

The following is a sample problem using Field Nos. 1 and 2 from Table 7.1, page 7-9, for computing pumping time based on a maximum condition using peak consumptive rates shown in Table 2.5 on page 2-22.

Corn - 3.5" net application - peak CU is 0.305"/day

Sorghum - 3.0" net application - peak CU is 0.28"/day

For corn - estimated field efficiency is 85%

For sorghum - estimated field efficiency is 70%

The peak daily water need is

$$\text{Corn} - \frac{(0.305''/\text{day}) \times (80 \text{ acres})}{.85} = 28.7 \text{ Ac. In.}$$

$$\text{Sorghum} - \frac{(.28''/\text{day}) \times (80 \text{ acres})}{.70} = \underline{32.0} \text{ Ac. In.}$$

$$\text{Total} = 60.7 \text{ Ac. In./day}$$

Net water supply is 2.67 c.f.s.

2.67 c.f.s. = 2.67 Ac. In./hr.

Pumping time in hrs. to meet the peak need:

$$\frac{60.7}{2.67} \text{ Ac. In.} = 22.7 \text{ hrs.}$$

This would be a very close operating schedule allowing little down time for maintenance and repairs as well as restricting any flexibility in system operation.

There are several adjustments that could be made to accomplish a more realistic pumping schedule. One would be to reduce the sorghum acreage by 20 acres.

n - $\frac{(.28''/day) \times (60 \text{ acres})}{.70}$ = 24.0 Ac. In./day

(Same) 28.7 Ac. In./day

Total = 52.7 Ac. In./day

g time in hrs. to meet the peak need:

?.7 ÷ 2.67 = 19.7 hrs. (use 20)

ould be a more reasonable daily pumping schedule for peak use
s and allows more system flexibility for needed adjustments
ration.

tion Water Management - Refer to Table 7.2, page 7-10. This
is the same as the reverse side of Form KS-EN-?16 (Rev.) It
be used to document and certify whether an irrigator is
lishing irrigation water management when operating his irrigation
.

topographic or water supply information is needed as noted
ns 3 and 4, this form can be completed after conferring with
rigator as to how he operates his irrigation system.

USDA
SCS

-Table 7.1-

DESIGN SHEET FOR SURFACE IRRIGATION SYSTEMS

REV. 3/79
(File Code ENG-19)

Farmer *Example* Field Office ____

Legal Descr. ____ Plan No. ____

Available Water 1200 g.p.m. 2.67 c.f.s. Design from Part 4 or 6 of the Kansas Irrigation Guide.

Furrow or Corrugation

Field No.	1	2
Area-acres	80	80
Soils	Rich'd	Dalhart
Irrig. Design Group	3	7
Intake family	0.3	1.0
Crop	Corn	Sorghum
Net moist. replaced (in.)	3.5	3.0
Design slope (%)	0.4	0.2
Length of run (ft.)	2600	1300
Furrow Spacing (in.)	30	40
Max. stream (gpm)	26	50
Unit stream (gpm/100')	1.0	3.5
Furrow stream (gpm) Initial	–	46
Cutback	–	23
Reuse	26	–
No. rows/set Initial	46	26
Cutback	–	52
Gross water used (in.)	4.1	4.3
Field eff. (%)	85	70
Time to reach end of row (hrs.) *	3.3	1.0
Time required (hrs.)	16.0	2-2-4

* Not to exceed 20 % of total time/set-hrs.

Border or Basin

Field No.	3	4
Area-acres	60	100
Soils	Harney	Naron
Irrig. Design Group	3	7
Intake family	0.3	1.0
Crop	Alfalfa	Grass
Net moist. replaced (in.)	4.0	3.0
Design slope (%)	0.4	0.7
Length of run (ft.)	2600	1200
Border width (ft.)	27	36
Unit stream (cfs/100')	0.0019+	0.0062
cfs/ft. width (Q/w)=(Lxq)	0.0494	0.0744
Border stream ~~(cfs)~~(gpm)	600	1200
Flow depth d (ft.)	0.21	0.23
Border ht. (ft.)=d+0.2	0.41	0.43
No. Borders per set	2	1
Field eff. (%)	50	65
Avg. time/set (hrs.)**	10	1.7

**

$$\text{Time/set(hrs.)} = \frac{0.23 \times \text{net application (in.)}}{\text{eff.}(\%) \times \text{unit stream } q(\text{cfs})}$$

+ Note: Corrugations required to provide adequate spread of border stream.

Designed by *Example* Date ____

Approved by ____ Date ____

<u>Note</u>: Record irrigation water management documentation notes on back after Irrigation System has been applied and is in operation.

Table 7.2
IRRIGATION WATER MANAGEMENT
FOR
GRAVITY IRRIGATION SYSTEMS

Check List:

1. The irrigator has the knowledge and capability to manage and apply irrigation water so as to meet the objectives of sound irrigation water management. Yes ✓ No ____.

2. The system is generally being operated as outlined on design sheet, Form KS-EN-216(Rev.), with needed adjustments being made. Yes ✓ No ____.

3. Fields 1, 2, ___, and ___, have been leveled in accordance with SCS standards. Profiles and cross sections (minimum of two each per 40 acres) are attached for fields 3, 4, ___, and ___, documenting that irrigation water management can be accomplished. Topographic planning or grid surveys which satisfy the above criteria may be used in lieu of profiles and cross sections for documentation purposes. (Attach surveys to this sheet.)

4. The water supply is 1200 gpm based upon flow meter or field tests (circle one). Frequency of irrigation is 12 days. If the system operation is based on other than full irrigation, will it meet all conditions except peak consumptive use requirements? Yes ✓ No ____.

5. Is water quality within acceptable limits? Yes ✓ No ____.

6. Furrow streams meet accepted criteria as to soil intake and capacity and are non-erosive. Yes ✓ No ____.

7. Tailwater control system(s) is installed, functional, and adequate. Yes ✓ No ____.

8. Is the water distribution system efficient and adequate? Yes ✓ No ____.

9. Acres of irrigation water management. 160

Remarks:

Prepared and certified by: Example

Date: ____________________

PART 8 - WHEN AND HOW MUCH WATER TO APPLY

A. When to Irrigate

The determination of when a crop needs irrigation based on crop appearance is discussed briefly in Part 2E. Utilization of crop moisture stress signs is usually a last resort approach to irrigation application timing. Serious moisture stress reduces yields generally and sometimes drastically for some crops such as corn. Other methods of determining when irrigation is needed consist of estimating the soil moisture by observation of the soil at different moisture contents; by making measurements of the soil moisture in the crop root zone; or simply by using a bookkeeping account of moisture received by the crop.

1. Feel and Appearance Method - This method of determining soil moisture content, by hand squeeze of a soil sample and by feel and general observation, is a common method used because it is fairly simple and needs no equipment except a soil probe, auger or spade to extract the soil samples. The pictures on page 8-3, 8-4, and 8-5 illustrate the hand squeeze method. This method is a means of estimating the percent of available soil moisture in relation to field capacity. When field capacity is known the amount of moisture needed is easy to calculate. The chart, Table 8.1 on page 8-2, gives descriptive soil behavior by feel and appearance for various moisture contents. This same chart information is found on the back of Forms ENG-KA-216 and 217.

   Although gauging moisture conditions by feel and appearan is not the most accurate method, with experience and judgment the irrigator should be able to estimate the moisture level within a reasonable degree of accuracy. The photographs and chart descriptions of soil moisture conditions mentioned above can be used to aid in the dete mination of moisture present in the soil and when irrigation water should be applied. Generally, irrigation is needed when approximately 50 percent of available moistur remains in the root zone.

   Soil samples taken for moisture measurement should be mad in that part of the soil from which plant roots extract their moisture. One sample should be taken from the uppe quarter of the root zone and one or two more samples at lower levels. If moisture-extraction depth for a given crop is 36 inches, for example, sampling probably should be at about 6 and 24 inches.

Table 8.1

Guide for Judging How Much Moisture is Available for Crops

Available Soil Moisture Remaining	Feel or Appearance of Soil			
	Loamy Sand or Sand	Sandy Loam	Loam and Silt Loam	Clay Loam or Silty Clay Loam
0 percent Wilting point	Dry, loose, single grained; flows through fingers.	Dry and loose; flows through fingers.	Powdery dry; sometimes slightly crusted but breaks down easily into powder.	Hard, baked, cracked; has loose crumbs on surface in some places.
25 percent	Appears to be dry; does not form a ball under pressure.	Appears to be dry; does not form a ball under pressure.	Somewhat crumbly but holds together from pressure.	Somewhat pliable; balls under pressure.
50 percent	Appears to be dry, will not form a ball under pressure.	Tends to ball under pressure but seldom holds together.	Forms a ball under pressure; somewhat plastic; slicks slightly with pressure.	Forms a ball; ribbons out between thumb and forefinger.
75 percent	Sticks together slightly; may form a very weak ball under pressure.	Forms weak ball that breaks easily; does not slick.	Forms ball; very pliable; slicks readily if relatively high in clay.	Ribbons out between fingers easily; has a slick feeling.
At field Capacity (100 percent)	On squeezing, no free water appears on soil but wet outline of ball is left on hand.	On squeezing, no free water appears on soil but wet outline of ball is left on hand.	On squeezing, no free water appears on soil but wet outline of ball is left on hand.	On squeezing, no free water appears on soil but wet outline of ball is left on hand.

Note: Ball is formed by squeezing a handful of soil very firmly.

MODERATELY FINE TEXTURE

Clay Loams and Silty Clay Loams

25% Available Moisture
Crumbles readily, will hold together but "balls" with difficulty and breaks easily.

50% Available Moisture
Does not crumble, forms readily, will "ball" with pressure.

75% Available Moisture
Forms "ball" readily, will "ribbon" out between thumb and forefinger. Somewhat slick feeling.

100% Available Moisture
Easily "ribbons" out. Has "slick" feeling.

MEDIUM TEXTURE

Loams and Silt Loams

25% Available Moisture
Crumbles easily, tends to hold together from hand pressure.

50% Available Moisture
Somewhat crumbly, will hold together in hand with pressure.

75% Available Moisture
Forms "ball" readily, will "slick" slightly with pressure.

100% Available Moisture
Forms "ball" easily, fairly friable, "slicks" readily.

COARSE TEXTURE

Sandy Loams and Loamy Sands

25% Available Moisture
Dry, loose, flows through fingers.

50% Available Moisture
Looks dry, will not form ball with pressure.

75% Available Moisture
Will form loose ball under pressure, will not hold together even with easy handling.

100% Available Moisture
Forms weak ball, breaks easily, will not "slick".

2. <u>Moisture Tension Instrument</u> - A tensiometer consists of a sealed water-filled tube equipped with a vacuum gauge on the upper end and a porous ceramic tip on the lower end. Tensiometers show "soil moisture tension" or "soil suction."

The suction generated when the crop roots remove water from the soil draws water from the tensiometer tube through the porous tip and causes the gauge to register a partial vacuum. The drier the soil the greater the vacuum registered and the higher the reading.

When rainfall or irrigation renews the soil water the tensiometer partial vacuum pulls water back into the tube causing the gauge to read lower (Figure 8-1).

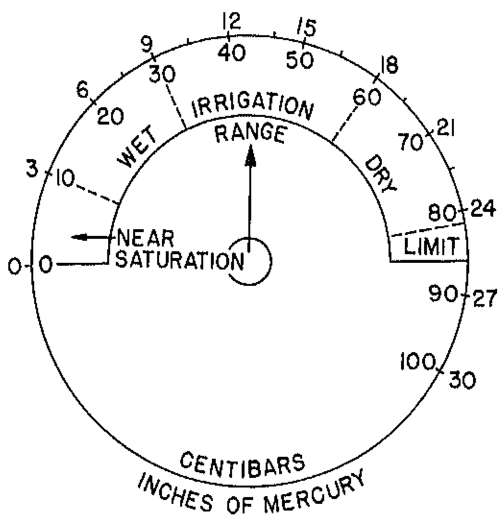

Figure 8-1. Tensiometer Dial

(a) Placement of Tensiometers - Tensiometers are set at a station where moisture in the soil is to be monitored. A station consists of two or more tensiometers of different lengths placed near one another, usually in the crop row.

Two stations may be enough in a field with uniform soil and slope. One station should be near the upper

end of the field and the other near the lower end. When placing tensiometers, the following should be kept in mind.

(1) Place in the row and angle downward toward the furrow. The shallow tensiometer tip should be under the edge of the furrow and the deep tensiometer tip under the center of the furrow.

(2) Measuring stations should be in representative areas of the field. Tensiometers should not be placed in low spots.

(3) Stations should be at points where the plant population is representative of the field.

(4) The soil around the tensiometer should not be compacted. The station should be approached from a row other than the one in which the tensiometer is placed.

(b) Depth of Installation - Depth of the tensiometer installation is determined by the active root zone of the crop. This active root zone depends upon the crop, stage of growth, and depth of soil (see Table 8.2). For example, for a crop of corn on a deep soil, tensiometers installed at a depth of 12 inches and 24 inches are recommended for each station.

Table 8.2

Recommended Depth for Setting Tensiometers

Irrigation Depth of Active Root Zone (Inches)	Shallow Tensiometer (Inches)	Deep Tensiometers (Inches)
18	8	12
24	12	18
36	12	24
48 or more	18	36

(c) Determining When to Irrigate - The shallow tensiometers at both ends of the field tell when to start irrigating. The gauge reading that indicates need for irrigation will be different for different soils (see Table 8.3).

Table 8.3

Interpretation of Tensiometer Readings

Condition	Dial Reading		Interpretation
	Inches of Mercury	Centi-bars	
Nearly Saturated	 3	0 10	Near saturated soil often occurs for a day or two following irrigation. Danger of water-logged soils, a high water table, poor soil aeration, or the tensiometer may have broken tension, if readings persist.
Field Capacity	 6 9	11 20 30	Field capacity. Irrigations discontinued in this range to prevent waste by deep percolation and leaching of nutrients below the root zone. Sandy soils will be at field capacity in the lower range, with clayey soil at field capacity in the upper range.
Irrigation Range	12 15 18	40 50 60	Usual range for starting irrigations. Soil aeration is assured in this range. In general, irrigations start at readings of 30-40 in sandy textured soils (loamy sands and sandy loams). Irrigations usually start from 40-50 on loamy soils, (very fine sandy loams and silt loams). On clay soils (silty clay loams, silty clays, etc.) irrigations usually start from 50-60. Starting irrigations in this range insures maintaining readily available soil moisture at all times.
Dry	21	70	This is the stress range. However, crop not necessarily damaged or yield reduced. Some soil moisture is readily available to the plant but is getting dangerously low for maximum production.
	24	80	Top range of accuracy of tensiometer, readings above this are possible but the tensiometer will break tension between 80 to 85 centibars.

3. <u>Electrical Resistance Blocks</u> - This method uses small gypsum blocks and a portable resistance meter to measure soil moisture content.

Gypsum blocks are made by casting gypsum around a pair of stainless steel wires or wire grids. These wires are attached to lead wires which are plugged into the meter. When the blocks are placed in contact with the soil, the moisture content of the gypsum tends to equal the moisture content of the soil. Because the electrical resistance of the wires in the gypsum varies with the moisture content, a measurement of electrical resistance by the meter is a good indication of the soil moisture content. The drier the soil, the greater the electrical resistance and vice versa. Some meters are constructed so that a low gauge reading indicates high soil moisture.

(a) Placement of Blocks - The location and depth of installation of these blocks are the same as for tensiometers. The gypsum blocks should be placed in the soil in the rooting zone of the crop as early in the season as is practical and left in the soil throughout the growing season.

(1) The electrical resistance blocks should be thoroughly soaked in a pail of water before installing (see manufacturer's recommendations for soaking time). Soaking removes air from the blocks and insures accurate readings of the soil moisture.

(2) A soil probe or auger can be used to bore a hole in the row slightly larger than the gypsum block. The hole should angle toward the furrow.

(3) The last three inches of soil removed from the hole should be crumbled and put back in the hole. About one-half cup of water should be poured into the hole so a slurry of mud is formed in the bottom.

(4) The blocks should be pushed into the hole with the soil probe, or one-half inch diameter electrical conduit, setting them solidly in the bottom with a firm push of the probe. <u>Firm contact between the blocks and surrounding soil must be made</u>.

(5) The hole should then be filled with soil, 3 or 4 inches at a time, tamping the soil firmly as the hole is filled.

(6) The wire leads from the two blocks should be brought to a single station midway between the holes and tied to a stake with the wires separated. The wires should be color coded or otherwise marked for proper identification so that connection to the meter can be readily made at times of reading.

Table 8.4

Interpretation of Readings on the Electrical Resistance Meters

Condition	Electrical Resistance		Interpretation
	Ohms	Meter Readings	
Nearly Saturated	Less than 300	200 to 180	Near saturated soil often occurs for a few hours following irrigation. Danger of water-logged soils, a high water table, poor soil aeration if reading persists for several days.
Field Capacity	300 to 500	180 to 170	Field capacity. Irrigations discontinued in this range to prevent waste by deep percolation and leaching of nutrients below the root zone.
Irrigation Range	3200 to 7000	120 to 80	Usual range for starting irrigations. Soil aeration is assured in this range. Starting irrigations in this range insures maintaining readily available soil moisture at all times.
Dry	Above 7000	Less than 80	This is the stress range. However, crop not necessarily damaged or yield reduced. Some soil moisture is available to the plant but is getting dangerously low for maximum production.

(b) Meter Readings as Related to Soil Moisture - Table 8.4, page 8-10, is a guide to interpreting meter readings as they relate to soil moisture conditions. There will be differences in electrical resistance readings due to frequency of the A.C. resistance meters. Each company that sells electrical resistance meters for measuring soil moisture has recommendations which are provided with the meters.

(c) Determining When to Irrigate - The meter readings that indicate the need for irrigation will be different for various textured soils (see Table 8.5, below).

Irrigation should be started when the average meter readings from the shallow blocks reach the meter readings indicated in Table 8.5. Adjustments have been made in the recommended meter reading to allow for 5 to 8 days to completely irrigate all fields supplied by the water source.

Table 8.5

Electrical Resistance Readings for Starting Irrigation of Corn and Grain Sorghum

Soil Texture	Meter Readings on Shallow Block	
	Meter Reading	Electrical Resistance (Ohms)
Loamy sands Sandy loams	120	3200
Very fine sandy loams Silt loam	100	4800
Clay loams Silty clay loams	80	7000

4. Moisture Accounting Method - This method, sometimes called the bookkeeping method, is a daily accounting of soil moisture withdrawals and moisture intake or deposit into the soil. Daily crop consumptive use based on stage of crop growth and climatic conditions, such as temperature and hours of sunshine, is the soil moisture withdrawal, and effective rainfall is the moisture intake. When the soil moisture "account" is reduced to a certain point, irrigation is applied to bring soil moisture up to field capacity. A more detailed explanation of the moisture accounting procedure is given in the Irrigation Chapter of the SCS Engineering Field Manual on pages 15-40 to 15-50.

Agricultural consulting services are available that provide irrigation scheduling services using computer methods for determining potential evapo-transpiration and for maintaining soil moisture accounting. These services also normally include weekly field visits to monitor soil moisture levels.

5. <u>Direct Gas Pressure Method</u> - This method involves the use of a volumeter to measure specific amount of a soil sample, and the Carbide Gas Moisture Tester (Speedy Tester) to measure pressure. A soil sample is placed in a pressure chamber with calcium carbide where the moisture in the soil mixes with the carbide creating a pressure which relates directly to the amount of moisture in the soil sample. This pressure is recorded on a gauge attached to the pressure chamber of the tester. The pressure gauge reading can be converted by chart (Table 8.6, page 8-14) to percent moisture of the soil sample. Percent moisture is based on dry weight of the soil sample. Oven-dry testing of a few samples is needed to properly calibrate the gauge readings.

   Field test results with the gas pressure method are usually within $\pm$ 2.0 percent of soil moisture of the correct amount as determined by oven-dry samples. For example, if the gas pressure tested sample is found to show 20 percent moisture content, then correct amount would be expected to be some value between 22 percent and 18 percent. The variation is in the range of $\pm$ 2/20 or a $\pm$ variation of 10 percent for this case.

   With precision sample weighing and very careful attention to details in operating the tester, the results might be improved to $\pm$ 1.0 percent of soil moisture. Some of the conditions that can cause poor pressure test results are failure to follow instructions in use of the equipment, inadequate mixing of soil and carbide, inaccurate quantities of mixing ingredients, carbide too old or impure, pressure leak at the cap or other connection, pressure chamber and ingredients too cold or possibly too hot spoiling reaction intensity and timing, and allowing steel balls to strike gauge end in shaking the sample in the tester.

   Soil moisture percent obtained by the tester can be compared to values in Table 8.7, page 8-18, to arrive at an approximate answer for the portion of available water capacity (AWC) remaining in the root zone. For example, assume a soil sample is clay loam taken at a depth of 24 inches below the surface and the field test pressure gauge reading is

18.8. From Table 8.6 this gauge reading represents 22.3 percent soil moisture. From Table 8.7 the soil moisture percent at field capacity (FC) is 26.3 and the soil moisture percent at wilting point (WP) is 16.3. So the 22.3 percent moisture of the sample is 6.0 percent moisture above WP and 4.0 percent moisture below FC. Then the portion of the available water capacity remaining at this depth in this location is approximately 60 percent (26.3% soil moisture is 100% of AWC and 16.3% soil moisture is 0% of AWC for this case).

When the available water capacity in the root zone is estimated to be approximately 50 percent depleted, then irrigation should begin.

It is best to first test each sampling station when moisture is known to be at field capacity for the two or more depths to be tested. Then the value for percent moisture at field capacity relates directly to the site and should be more accurate than values from Table 8.7.

Details of the Direct Gas Pressure Method are given in the Irrigation Chapter of the SCS Engineering Field Manual on pages 15-50 to 15-58.

Table 8.6

Carbide Moisture Tester Conversion Chart

Gauge Read.1/	Oven Dry Moisture-Percent									
	0	.1	.2	.3	.4	.5	.6	.7	.8	.9
2	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9
3	3.0	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9
4	4.0	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9
5	5.1	5.2	5.3	5.4	5.5	5.7	5.8	5.9	6.0	6.1
6	6.2	6.3	6.4	6.5	6.6	6.8	6.9	7.0	7.1	7.2
7	7.3	7.4	7.5	7.6	7.7	7.9	8.0	8.1	8.2	8.3
8	8.4	8.5	8.6	8.7	8.8	9.0	9.1	9.2	9.3	9.4
9	9.5	9.6	9.7	9.8	9.9	10.1	10.2	10.3	10.4	10.5
10	10.6	10.7	10.8	11.0	11.1	11.2	11.3	11.4	11.6	11.7
11	11.8	11.9	12.0	12.2	12.3	12.4	12.5	12.6	12.8	12.9
12	13.0	13.1	13.3	13.4	13.5	13.7	13.8	13.9	14.0	14.2
13	14.3	14.4	14.6	14.7	14.8	15.0	15.1	15.2	15.3	15.5
14	15.6	15.7	15.9	16.0	16.2	16.3	16.4	16.6	16.7	16.9
15	17.0	17.1	17.3	17.4	17.5	17.7	17.8	17.9	18.0	18.2
16	18.3	18.4	18.6	18.7	18.9	19.0	19.1	19.3	19.4	19.6
17	19.7	19.8	20.0	20.1	20.3	20.4	20.5	20.7	20.8	21.0
18	21.1	21.3	21.4	21.6	21.7	21.9	22.0	22.2	22.3	22.5
19	22.6	22.8	22.9	23.1	23.2	23.4	23.5	23.7	23.8	24.0
20	24.1	24.3	24.4	24.6	24.7	24.9	25.0	25.2	25.3	25.5
21	25.6	25.8	25.9	26.1	26.2	26.4	26.5	26.7	26.8	27.0
22	27.1	27.3	27.4	27.6	27.7	27.9	28.0	28.2	28.3	28.5
23	28.6	28.8	28.9	29.1	29.2	29.4	29.6	29.7	29.9	30.0
24	30.2	30.4	30.5	30.7	30.8	31.0	31.1	31.3	31.4	31.6
25	31.7	31.9	32.0	32.2	32.3	32.5	32.7	32.8	33.0	33.1
26	33.3	33.5	33.6	33.8	33.9	34.1	34.3	34.4	34.6	34.7
27	34.9	35.1	35.2	35.4	35.5	35.7	35.9	36.0	36.2	36.3
28	36.5	36.7	36.8	37.0	37.1	37.3	37.5	37.6	37.8	37.9
29	38.1	38.3	38.4	38.6	38.8	39.0	39.1	39.3	39.5	39.6
30	39.8	40.0	40.1	40.3	40.5	40.7	40.8	41.0	41.2	41.3
31	41.5	41.7	41.8	42.0	42.2	42.4	42.5	42.7	42.9	43.0
32	43.2	43.4	43.5	43.7	43.8	44.0	44.2	44.3	44.5	44.6
33	44.8	45.0	45.1	45.3	45.5	45.7	45.8	46.0	46.2	46.3

1/ Carbide Moisture Tester - 3 minute readings

B. How Much Water to Apply

Columns 3 and 10 of the irrigation design guide sheets, pages 4-15 to 4-41, give information on net and gross water needs for each irrigation when the available water capacity in the root zone is approximately half depleted. These values are for average conditions.

Another procedure for determining the amount of water to apply is shown below. The first thing needed in this procedure is a good estimate of the available water in the root zone at field capacity for a specific soil. Table 8.7, 8-18, has been developed to aid in this determination. Also needed is an estimate of the portion of available water capacity depleted from the root zone as determined by one of the previously mentioned methods. This information will give data on how much water is needed to bring the soil to field capacity.

Example #1 -

Soil is silt loam 0 to 12" with silty clay loam subsoil.

Depth to irrigate is 36". Samples are taken at 6" to 24" depths.

Test is made by feel and appearance method.

Sample from 6" depth fits description (Table 8.1) for 25 percent available soil moisture remaining and fits photograph No. 1, page 8-4.

The estimated irrigation need for the top 12 inches is (100-25) or 75 percent of AWC.

The sample from 24" depth, by description (Table 8.1) and photographs, page 8-3, is judged to fit half way between 50 percent and 75 percent available soil moisture remaining.

$\frac{(50 + 75)}{2}$ or 62 percent available soil moisture remaining.

The estimated irrigation need for 12" to 36" depth is (100-62) or 38 percent of AWC.

From Table 8.7, AWC for silt loam in 0 - 12" layer is 0.23"/inch, and AWC for silty clay loam below 12" depth is 0.19"/inch.

Estimated water need in 0 - 12" layer is (.75)(.23)(12") = 2.07".

Estimated water need below 12" is (.38)(.19)(24") = 1.73".

Net irrigation need is 2.07 + 1.73 = 3.80".

Example #2 -

Soil is fine sandy loam 0 to 24" and sandy loam below 24".

Depth to irrigate is 60".

Samples are taken at 6", 18" and 36" and tested by gas pressure method. Gauge readings top to bottom are 9.7, 12.8 and 10.0.

0 - 12" Depth

Gauge reading of 9.7 is 10.3 percent soil moisture (Table 8.6).

Then from Table 8.7 FC is at 19.5 percent moisture and AWC = 12.0 percent moisture range.

19.5 - 10.3 = 9.2 percent soil moisture below FC.

Percent of AWC deficient is 9.2/12.0 x 100 = 77%.

AWC is 0.18"/inch (Table 8.7).

Water needed top 12 inches is (.77)(.18)(12") = 1.66".

12 to 24" Depth

Gauge reading of 12.8 is 14.0 percent moisture.

FC is at 18.2 percent moisture and AWC = 10.2 percent moisture range.

18.2 - 14.0 = 4.2 percent soil moisture below FC.

Percent of AWC deficient is 4.2/10.2 x 100 = 41%.

AWC is 0.16"/inch.

Water needed 12" to 24" zone is (.41)(.16)(12") = 0.79".

24 to 60" Depth

Gauge reading of 10.0 is 10.6 percent moisture.

FC is at 13.4 percent moisture and AWC = 7.8 percent moisture range.

13.4 - 10.6 = 2.8 percent moisture below FC.

Percent of AWC deficient is 2.8/7.8 x 100 = 36%.

AWC is 0.13"/inch.

Water needed 24" to 60" zone is (.36)(.13)(36") = 1.68.

Water needed to fill root zone to FC is 1.66 + 0.79 + 1.68 = 4.13".

Net irrigation application should be 4.0".

Table 8.7

Average Available Water Capacity for Kansas Soils

0 to 12" Soil Layer

Soil Texture	Avg. Bulk Density At F.C.	Percent Moisture 1/ F.C.	2/ W.P.	3/ A.W.C.	4/ W.P./F.C.	Inches per Inch 1/ F.C.	2/ W.P.	3/ A.W.C.
Sand	1.60	8.7	3.5	5.2	40	0.14	0.06	0.08
Loamy sand	1.60	11.9	4.5	7.4	38	0.19	0.07	0.12
Sandy loam	1.55	15.4	5.8	9.6	38	0.24	0.09	0.15
Fine sandy loam	1.50	19.5	7.5	12.0	38	0.29	0.11	0.18
Loam	1.45	23.6	9.2	14.4	39	0.34	0.13	0.21
Silt loam	1.40	27.2	10.9	16.3	40	0.38	0.15	0.23
Silty clay loam	1.35	28.8	13.0	15.8	45	0.39	0.18	0.21
Sandy clay loam	1.40	27.0	13.5	13.5	50	0.38	0.19	0.19
Clay loam	1.40	27.3	15.1	12.2	55	0.38	0.21	0.17
Silty clay	1.30	28.7	18.0	10.7	61	0.37	0.23	0.14
Clay	1.25	29.4	20.1	9.3	68	0.37	0.25	0.12

Below 12"

Soil Texture	Avg. Bulk Density At F.C.	Percent Moisture 1/ F.C.	2/ W.P.	3/ A.W.C.	4/ W.P./F.C.	Inches per Inch 1/ F.C.	2/ W.P.	3/ A.W.C.
Sand	1.70	7.0	3.0	4.0	43	0.12	0.05	0.07
Loamy sand	1.70	10.0	4.2	5.8	42	0.17	0.07	0.10
Sandy loam	1.65	13.4	5.6	7.8	42	0.22	0.09	0.13
Fine sandy loam	1.60	18.2	8.0	10.2	44	0.29	0.13	0.16
Loam	1.55	22.6	10.3	12.3	46	0.35	0.16	0.19
Silt loam	1.50	26.8	12.9	13.9	48	0.40	0.19	0.21
Silty clay loam	1.45	27.6	14.5	13.1	52	0.40	0.21	0.19
Sandy clay loam	1.50	26.0	14.8	11.2	57	0.39	0.22	0.17
Clay loam	1.50	26.3	16.3	10.0	62	0.39	0.24	0.15
Silty clay	1.40	27.9	18.8	9.1	67	0.39	0.26	0.13
Clay	1.35	28.8	20.8	8.0	72	0.39	0.28	0.11

1/ Field capacity

2/ Wilting point

3/ Available water capacity

4/ Percent of field capacity at wilting point

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TABLE 8.8

EQUIVALENTS - WATER VOLUME, WEIGHT, & FLOW

THIS UNIT	TIMES THIS	GIVES THIS UNIT
VOLUME:		
1 gallon (gal)	231 0.1337	cubic inches (cu. in.) cubic feet (cu. ft.)
1 million gallon (mg)	3.0689	acre-feet (acre-ft.)
1 cubic foot	1,728 7.48	cubic inches gallons
1 acre-inch (amount of water to cover one acre one inch deep)	3,630 27,154 0.0833	cubic feet gallons acre-feet
1 acre-foot (amount of water to cover one acre one foot deep)	43,560 325,829 12	cubic feet gallons acre-inches
1 cubic meter	35.3 264	cubic feet gallons
WEIGHT:		
1 gallon	8.33	pounds (lb.)
1 cubic foot	62.4	pounds
1 cubic meter	2,203	pounds
FLOW:		
1 gallon per minute (gpm)	0.00223 1,440	cubic feet per second (cfs) gallons per day (24 hours)
1 million gallons per 24 hours (mgd)	1.547 695	cubic feet per second gallons per minute
1 cubic foot per second	7.48 448.8 26,928 646,272 0.992 1.983 0.0283 1.7	gallons per second gallons per minute gallons per hour gallons per day (24 hours) acre-inches per hour acre-feet per day (24 hours cubic meters per second cubic meters per minute

TABLE 8.9

AREA UNITS:	LENGTH UNITS:
1 acre = 43,560 square feet 1 acre = 160 square rods 1 acre = 0.405 hectare	1 mile = 5,280 feet 1 mile = 320 rods 1 rod = 16.5 feet 1 mile = 1.609 kilometers

TABLE 8.10

Volume of Water Applied for Various Flow Rates and Time Rates

Flow Rate	Volume Applied			
gpm	1 Hr. acre-inches	8 Hrs. acre-inches	12 Hrs. acre-inches	1 Day acre-inches
100	0.22	1.77	2.65	5.3
200	0.44	3.54	5.31	10.6
300	0.66	5.31	7.96	15.9
400	0.88	7.08	10.6	21.2
500	1.11	8.85	13.3	26.5
600	1.33	10.6	15.9	31.9
700	1.55	12.4	18.6	37.2
800	1.77	14.2	21.2	42.5
900	1.99	15.9	23.9	47.8
1000	2.21	17.7	26.5	53.1
1100	2.43	19.5	29.2	58.4
1200	2.65	21.2	31.8	63.7
1300	2.87	23.0	34.5	69.0
1400	3.10	24.8	37.2	74.3
1500	3.32	26.5	39.8	79.6
1800	3.98	31.8	47.7	95.5
1900	4.20	33.6	50.4	100.8
2000	4.42	35.3	53.1	106.0
2100	4.64	37.1	55.7	111.4
2200	4.86	38.9	58.3	116.7
2300	5.08	40.7	61.0	122.0
2400	5.30	42.4	63.6	127.3
2500	5.53	44.2	66.3	132.6

TABLE 8.11

Acres in a Rectangular Field

Length of Field (Feet)	Width of Field (Feet)						
	660	990	1320	1650	1980	2310	2640
660	10.0	15.0	20.0	25.0	30.0	35.0	40
825	12.5	18.8	25.0	31.2	37.5	43.8	50
990	15.0	22.5	30.0	37.5	45.0	52.5	60
1155	17.5	26.2	35.0	43.8	52.5	61.2	70
1320	20.0	30.0	40.0	50.0	60.0	70.0	80
1485	22.5	33.8	45.0	56.2	67.5	78.8	90
1650	25.0	37.5	50.0	62.5	75.0	87.5	100
1815	27.5	41.2	55.0	68.8	82.5	96.2	110
1980	30.0	45.0	60.0	75.0	90.0	105	120
2145	32.5	48.8	65.0	81.2	97.5	114	130
2310	35.0	52.5	70.0	87.5	105.0	122	140
2475	37.5	56.2	75.0	93.8	112.5	131	150
2640	40.0	60.0	80.0	100	120	140	160

TABLE 8.12

Acres in an Irrigation Set

Length of Rows (Feet)	Number of Rows per Set - 30-inch Rows									
	10	20	30	40	50	60	70	80	90	100
600	0.38	0.76	1.1	1.5	1.9	2.3	2.7	3.0	3.4	3.8
825	0.47	0.95	1.4	1.9	2.4	2.8	3.3	3.8	4.3	4.7
990	0.57	1.1	1.7	2.3	2.8	3.4	4.0	4.5	5.1	5.7
1155	0.66	1.3	2.0	2.7	3.3	4.0	4.6	5.3	6.0	6.6
1320	0.76	1.5	2.3	3.0	3.8	4.5	5.3	6.1	6.8	7.6
1485	0.85	1.7	2.6	3.4	4.3	5.1	6.0	6.8	7.7	8.5
1650	0.95	1.9	2.8	3.8	4.7	5.7	6.6	7.6	8.5	9.5
1815	1.0	2.1	3.1	4.2	5.2	6.3	7.3	8.3	9.4	10.4
1980	1.1	2.3	3.4	4.5	5.7	6.8	8.0	9.1	10.2	11.4
2145	1.2	2.5	3.7	4.9	6.2	7.4	8.6	9.8	11.1	12.3
2310	1.3	2.7	4.0	5.3	6.6	8.0	9.3	10.6	11.9	13.3
2475	1.4	2.8	4.3	5.7	7.1	8.5	9.9	11.4	12.8	14.2
2640	1.5	3.0	4.5	6.1	7.6	9.1	10.6	12.1	13.6	15.2

Examples of Calculations Using Tables 8.8, 8.9, 8.10, 8.11, and 8.12

1. Given: Irrigated field - dimensions = 1,320 ft. wide x 2,640 ft. long. Meter reading = 160.8 ac. ft. before irrigation and 188.8 ac. ft. after irrigation.

   Find: Ac. ft. applied = (188.8 - 160.8) = 28 ac. ft.
   Ac. in field (Table 8.11) = 80 ac.
   Depth applied = ac. ft. applied ÷ ac. = depth in ft.
   = (28 ÷ 80) = 0.35 ft. x 12 in./ft.
   = 4.2 in.

2. Given: Same field as above, area = 80 ac. Meter reading = 53,984,000 gallons before irrigation and 60,935,424 gallons after irrigation.

   Find: Gallons applied = (60,935,424 - 53,984,000) = 6,951,424 gallons.
   Ac. in. applied = 6,951,424 ÷ 27,154 (Table 8.8)
   = 256 ac. in.
   Depth applied = (256 ÷ 80 ac.) = 3.2 in.

3. Given: Same field as above, pump discharge = 1,200 gallons/minute
   Irrigation time = 4 days

   Find: Ac. in. applied = 4 days x 63.7 ac. in. (Table 8.10) = 254.8 ac. in.
   Depth applied = (254.8 ÷ 80) = 3.2 in.

4. Given: Well delivery = 1,040 gpm. Row length = 2,640 ft. Row width = 40 in.
   Furrow stream = 46 gpm. Irrigation time = 16 hrs. Reuse system.

   Find: Number of rows per irrigation set = (1,380 ÷ 46) = 40 rows
   Area of set (Table 8.12) = 6.1 ac. x (40 ÷ 30) = 8.1 ac.
   (increase the area from 30 in. row spacing shown in table to 40 in. spacing)
   Water applied = 1,040 gpm ÷ 448.8 = 2.317 cfs x 0.992 = 2.298 ac. in./hr. x 16 hrs. = 36.8 ac. in.
   Depth applied = (36.8 ÷ 8.1) = 4.5 in.

Part 9 - IRRIGATION TAILWATER RECOVERY SYSTEMS

A. Procedure for Design of Irrigation Tailwater Embankment Ponds

1. Embankment fills made to impound irrigation tailwater will meet the design requirements and specifications listed in the Kansas Standard and Specifications for Pond-378.

2. Storage requirements for irrigation tailwater will be determined using the same criteria as for tailwater pits.

B. Procedures for Design of Irrigation Tailwater Pits

1. Depth - Design water surface shall be at the flowline elevation of the inlet structure or 1 foot (0.3 m) below the lowest irrigable land elevation adjacent to the pit, whichever is lower. Retrievable tailwater depth shall be a minimum of 5 feet (1.5 m) and a maximum of 12 feet (3.6 m). Excavated depth (below design water surface elevation) shall be design water depth plus 1 foot (0.3 m).

2. Slopes and Top Width - Excavated and embankment slopes shall not be steeper than 3:1, except 2:1 slopes may be used for the sides of the pit in soils that will be stable at the slope. Slopes will usually not be flatter than 4:1, except that one or both ends may be flattened to 6:1 for ease of construction and cleanout.

   Minimum top width of berms and dikes shall be 8 feet (2.4 m).

3. Mechanical Inlet Structures - Inlet structures shall be provided to convey the tailwater and/or storm runoff into the pit without erosion damage to the entrance channel or sides of the pit. These structures may consist of chutes, drop structures, or pipes (minimum size - 10 inches (25 cm) in diameter) using corrugated metal, welded steel, plastic, concrete, or other approved material. Structures will be designed in accordance with the Kansas Standards and Specifications. Refer to the Kansas Supplement to Chapter 6 of the Engineering Field Manual; use standard plans when available. The inlet structures must have the capacity to satisfy the operating needs of the system.

4. Emergency Spillway or Storm Bypass - Pits shall be surrounded by berms and dikes to prevent surface water from entering the pits at points other than the mechanical inlet structure. A storm bypass or emergency spillway shall be provided which will pass the runoff from a 25-year, 24-hour frequency A.M.C. II storm. Tops of the berms and dikes shall be at least 1 foot (0.3 m) above the maximum water surface in the pit or the spillway, whichever is higher, when passing this storm.

5. Size

a. Condition A - Pumpback is intermittent. Volume of storage shall be designed on the basis of the following:

(1) Select T_i, which is the irrigation set time in hours. T_i is listed in Column 11, part 4, of the Kansas Irrigation Guide. The T_i selected should represent the most restrictive design condition for the system. For example, if both border and furrow irrigation methods are planned, furrow irrigation with a high water demand crop, such as corn, should be used to select T_i.

(2) The number of sets (N) to be irrigated with pump-back water per pump-back cycle is usually 2. The maximum number is 2 and the minimum is 1.

(3) Determine whether or not tailwater from the pump-back pump also enters the pit.

(4) T_p is the pump-back time in hours, $T_p = N \times T_i$.

(5) Discharge rate (q) in gallons per minute of the pump-back pump is determined by multiplying the primary source (Q) in gallons per minute by a variable factor (C_a). Values of C_a vary according to soil intake families. Table 9.1 below lists the values of C_a for the various intake families.

TABLE 9.1

Intake Family	C_a Factors Maximum	Median	Minimum
0.1 to 0.3	0.80	0.60	0.40
0.5	0.60	0.46	0.33
1.0 to 3.0	0.40	0.30	0.20

Values of q may be adjusted ±10 percent if needed to fit the pump discharge rates of commercial suppliers.

(6) The rate of tailwater flow into the collection pits is based on the intake rates of the contributing areas along with the discharge rates of wells, turn outs, and pumps delivering the irrigation water. Use a decimal percentage (%) of Q returning as tailwater from the percentages shown in Table 9.2 for the soil intake families listed.

TABLE 9.2

Intake Family	Percentage (% or %*) of Primary (Q) or Pump-back (q) flow delivered as Tailwater
0.1 to 0.3	20
0.5	15
1.0 to 3.0	10

(7) Also select from Table 9.2 a decimal percentage (%*) of pump-back flow q returning as tailwater.

(8) Find the total of the average field tailwater from the primary source (%Q) and the average tailwater from the pump-back flow (%*q) or (%Q + %q). This is the total tailwater inflow into the pit.

(9) To keep the tailwater system in equilibrium, the pump-back rate q of the pump-back pump minus the total inflow (%Q + %q) must equal the volume of the tailwater pit (V_s) in acre-inches,

or storage = (outflow - inflow)

or $V_s = \frac{q - (\%Q + \%q)}{450} \times T_p$ = acre-inches

(10) Example -

Given: Richfield silt loam, intake family = 0.3
$Q = 1{,}000$ gpm   Slope Group = 0.2%
$T_i = 16.3$ hrs. $N = 2$

Find: T_p, q, %Q, %*q, and V_s

(a) $T_p = NT_i = 2 \times 16.3 = 32.6$ hrs.

(b) From Table 9.1, $C_a = 0.6$ (median value)
$q = C_aQ = 0.6 \times 1{,}000 = 600$ gpm

(c) From Table 9.2, % = 20%, %* = 20%, then
%Q = 0.20 x 1,000 = 200 gpm, %*q = 0.20 x 600 = 120 gpm

(d) $V_s = \frac{q - (\%Q + \%^*q)}{450} \times T_p$

$V_s = \frac{600 - (200 + 120)}{450} \times 32.6$

$= 20.3$ acre-inches

b. Condition B - Where continuous pumping is desired and the inflow is sufficient both in rate and duration to sustain such a system, the sump, as a minimum, needs to be only large enough to accommodate the pumping. Pump-back (once started) is continuous as long as the irrigation continues uninterrupted. The maximum value of N shall be one (1). Pump-back rate (q) and the volume of storage (V_s) are determined as follows:

(1) The following equations may be used to determine the pump-back rate (q) in gallons per minute:

$$q = \frac{\%}{1 - \%^*} \times Q, \text{ where } \frac{\%}{1 - \%^*} = C_b, \text{ or}$$

$$q = C_b Q$$

Q, q, %, and %* are the same units as used for Condition A.

(2) C_b factors used to determine q are found in Table 9.3.

TABLE 9.3
C_b Factors

Estimated decimal % of discharge Q flowing into the pit											
0.10				0.15				0.20			
Estimated decimal % of pump-back rate q flowing into the pit											
None	0.10	0.15	0.20	None	0.10	0.15	0.20	None	0.10	0.15	0.20
Pump-back Factor C_b											
0.100	0.111	0.118	0.125	0.150	0.167	0.177	0.188	0.200	0.222	0.236	0.250

(3) Volume of tailwater storage (V_s) needed is determined using the following equation:

$$V_s = \frac{(\%Q) \times T_i}{450} = \text{acre-inches}$$

(4) Example -

Given: Q = 1,000 gpm, T_i = 16.3 hrs., % = 0.20, %* = 0.20

Find: C_b, q, and V_s

(a) $C_b = \frac{\%}{1 - \%^*} = \frac{0.20}{1 - 0.20} = 0.25$

or refer to Table 9.3 to find C_b

(b) $q = C_b Q = 0.25 \times 1{,}000 = 250$ gpm

(c) $V_s = \frac{(.20 \times 1{,}000) \times 16.3}{450}$

$= 7.2$ acre-inches

6. Excavated Volume

a. Approximate excavated volume (V_e) may be found as follows:

$V_e = 175\ V_s$ (ac. in.) = cubic yards

Example -

Given: Storage volume (V_s) of a pit = 20.3 acre-inches
Side Slopes = 3:1, End Slopes = 6:1 - 4:1
Depth = 8', Bottom Width = 50'

Find: Estimated excavation volume (V_e),
bottom length and actual excavated volume

$V_e = 175\ V_s = 175 \times 20.3 = 3{,}552.5$, use 3,553 cu. yds.

From Table 9.8, page 9-15, for b = 50', d = 8'

$L = 0.0456V - 44.3$

$L = 0.0456 \times 3{,}553 - 44.3 = 117.7$, use 118'

b. Actual excavated volume

$V_e = \frac{d}{162} (A_1 + 4M + A_2)$

$= \frac{8}{162} (198 \times 98 + 4 (158 \times 74) + 50 \times 118)$

$= \frac{8}{162} (72{,}072) = 3{,}559$ cu. yds.

7. Sample Problem

See figures 9-1 and 9-2 which are example field sheets filled out for a tailwater recovery pit.

USDA
SCS

FIELD SHEET: TAILWATER RECOVERY PIT

KS-ENG-9
Rev. 9/79

Owner Example Ident. No. ______

Legal Description ______ County ______

PIT DESIGN INFORMATION

System is continuous [ ] or intermittent [✓]. Check one.

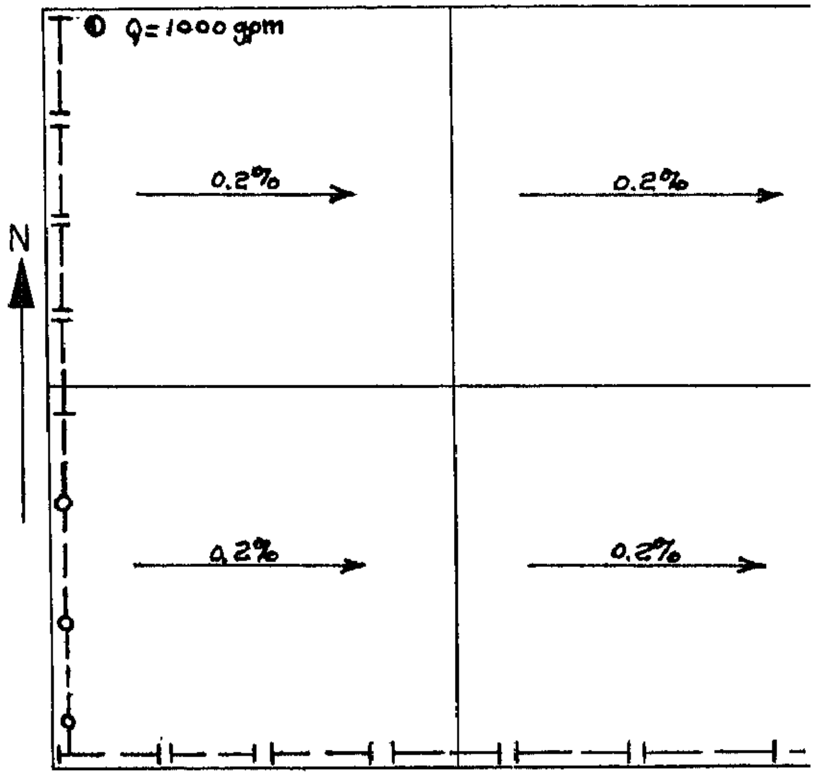
Crop Corn Field Slope 0.2%

Soil Richfield sl Int. Fam. 0.3

Row Spacing 40 in. N 2

T_i = 16.3 hrs. $\dot{Q}$ 1000 gpm

Pump-back tailwater (will) (~~will not~~) enter the pit.



Scale 1"=660' BM.–

Condition A

$T_p = NT_i$ = 2 x 16.3 = 32.6 hrs.

C_a = 0.6 $q = C_aQ$

q = 0.6 x 1000 = 600 gpm

% 0.20 %* 0.20

$$V_s = \frac{q - (\%Q + \%^*q)}{450} \times T_p$$

V_s = 20.3 ac. in.

Condition B

C_b = ______ $q = C_bQ$

q = ______ x ______ = ______ gpm

$V_s = \frac{\%QT_i}{450}$ = ______ ac. in.

Note: See design procedure in Part 9 of the Kansas Irrigation Guide

$V_e = 175\ V_s = 175 \times$ 20.3 = 3553 c.y.(e

Determine pit dimensions using Table 9.5 through 9.9 in Part 9 of the Kans Irrigation Guide.

Minimum depth = 7 ft.

Design dimensions Depth = 8 ft

Width = 50 ft. Length = 118 ft

Slopes, Ends 6 :1, Sides 3 :1
4 :1

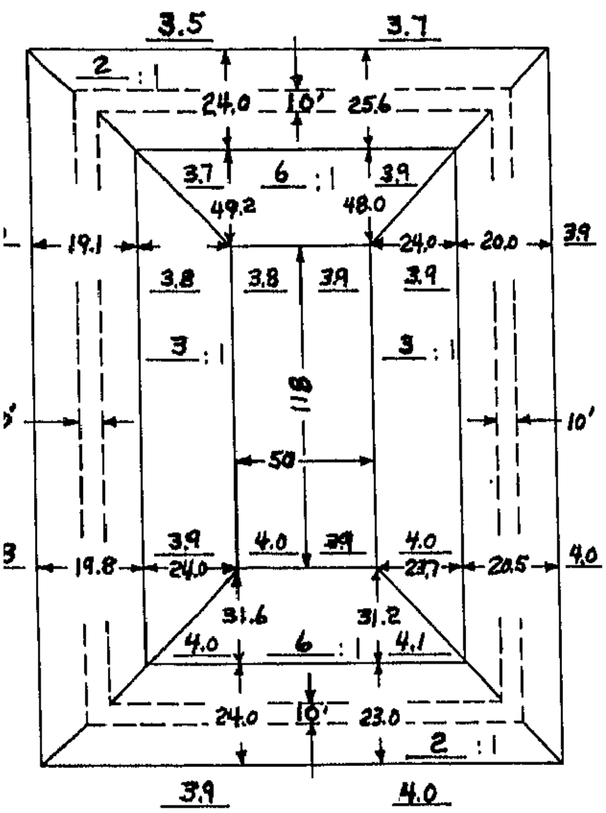
Remarks Locate inlet pipe on east side of pit as shown

Layout by Example Title ______ Date ______

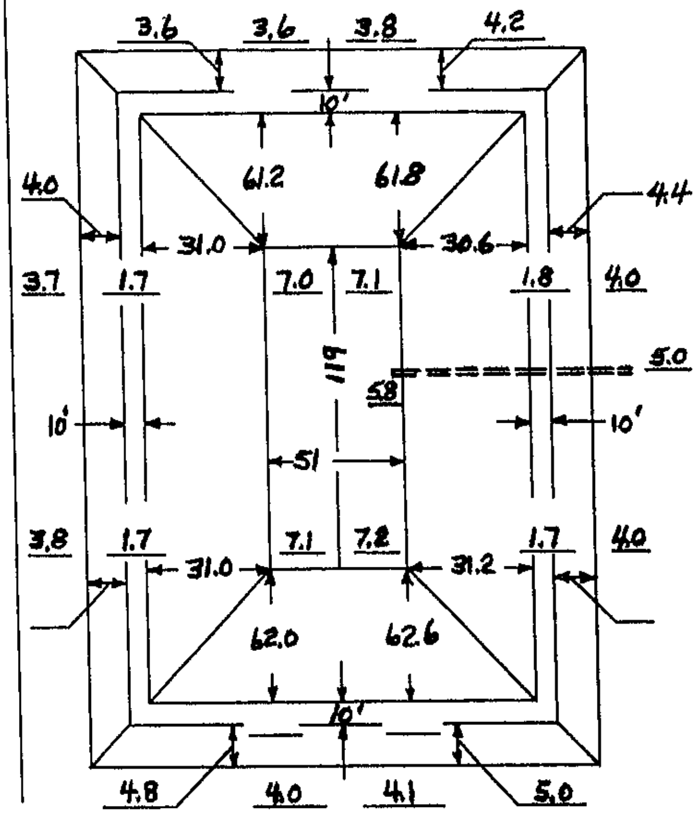
Checkout by ______ Title ______ Date ______

Figure 9-2

DESIGN LAYOUT



CONSTRUCTION CHECKOUT



Show pipe location

N

	B.S.	H.I.	F.S.	ELEV.
.M.	2.9	52.9		50.0
s. splwy.			3.9	49.0
s. berm			1.9	51.0
s. inlet			4.9	48.0
eld or TP			3.9	49.0
s. bot.			11.9	41.0

	B.S.	H.I.	F.S.	ELEV.
B.M.	3.0	53.0		50.0
Splwy. ck.			4.0	49.0
Berm min.			1.8	51.2
Inlet inv.			5.0	48.0
~~Field or~~ TP	2.1	48.1	7.0	46.0
Bot. ck.			7.1	41.0

ench mark elev. 50.0, Description Top of Steel Pin at Base of Corner Post

EXCAVATION PIT YARDAGE VOLUME

otal of top lengths 396 ft. Total of top widths 196 ft.

verage top length 198 ft. Average top width 98 ft.

op area = (Av. L.) 198 x (Av. W.) 98 = 19,404 sq. ft.

ottom area = (Av. L.) 118 x (Av. W.) 50 = 5,900 sq. ft.

4 median area = (Sum L.) 158 x (Sum W.) 74 = 46,768 sq. ft.
Add top and bottom av. lengths and widths

Sum = 72,072 sq. ft.

olume = $\frac{\text{av. depth x sum of areas}}{162} = \frac{8.0 \times 72{,}072}{162} = 3{,}559$ cu. yd.

TABLE 9.4

LENGTH DETERMINATION FOR EXCAVATED PITS

$$l = \frac{27V - 12d^3 - 3d^2w}{3d^2 + dw}$$

where: l = bottom length of the pit (feet)
V = volume, in cubic yards
w = bottom width (feet)
d = depth of pit (feet)

Side Slopes 3:1
End Slopes 3:1

Depth of Pit (d), feet

w	5	6	7	8	9	10	11	12
20	.154V-17.1	.118V-20.8	.0941V-24.6	.0768V-28.3	.0639V-32.2	.0540V-36.0	.0464V-39.9	.0402V-43.7
22	.146V-17.0	.113V-20.7	.0894V-24.4	.0735V-28.2	.0613V-32.0	.0520V-35.8	.0446V-39.6	.0388V-43.5
24	.139V-16.9	.107V-20.6	.0854V-24.3	.0704V-28.0	.0589V-31.8	.0500V-35.6	.0431V-39.5	.0375V-43.2
26	.132V-16.8	.102V-20.4	.0818V-24.2	.0675V-27.9	.0566V-31.6	.0482V-35.4	.0416V-39.2	.0363V-43.0
28	.126V-16.7	.0979V-20.3	.0775V-24.0	.0650V-27.7	.0545V-31.4	.0466V-35.2	.0403V-38.9	.0352V-42.7
30	.120V-16.7	.0937V-20.2	.0756V-23.9	.0625V-27.6	.0526V-31.3	.0450V-35.0	.0390V-38.8	.0341V-42.5
32	.115V-16.6	.0900V-20.2	.0728V-23.8	.0604V-27.4	.0510V-31.2	.0436V-34.9	.0378V-38.7	.0331V-42.4
34	.110V-16.5	.0865V-20.1	.0701V-23.7	.0582V-27.3	.0492V-31.0	.0422V-34.7	.0366V-38.5	.0322V-42.2
36	.106V-16.5	.0834V-20.0	.0676V-23.6	.0563V-27.3	.0476V-30.9	.0409V-34.6	.0356V-38.3	.0312V-42.0
38	.102V-16.4	.0804V-19.9	.0655V-23.5	.0545V-27.1	.0462V-30.8	.0398V-34.4	.0346V-38.2	.0304V-41.9
40	.0982V-16.4	.0776V-19.9	.0632V-23.4	.0528V-27.0	.0448V-30.7	.0386V-34.3	.0337V-38.0	.0296V-41.7
42	.0946V-16.3	.0750V-19.8	.0611V-23.4	.0512V-26.9	.0435V-30.6	.0375V-34.2	.0328V-37.8	.0288V-41.6
44	.0916V-16.3	.0726V-19.7	.0595V-23.3	.0496V-26.8	.0423V-30.5	.0367V-34.1	.0319V-37.8	.0282V-41.4
46	.0885V-16.2	.0704V-19.7	.0576V-23.2	.0483V-26.8	.0411V-30.4	.0356V-34.0	.0311V-37.6	.0274V-41.3
48	.0857V-16.2	.0682V-19.6	.0560V-23.2	.0469V-26.7	.0400V-30.2	.0346V-33.9	.0303V-37.5	.0268V-41.1
50	.0830V-16.2	.0662V-19.6	.0543V-23.1	.0456V-26.6	.0390V-30.1	.0338V-33.8	.0296V-37.4	.0262V-41.0
52	.0806V-16.1	.0644V-19.6	.0528V-23.0	.0454V-26.5	.0380V-30.0	.0330V-33.7	.0289V-37.3	.0256V-40.9
54	.0783V-16.1	.0635V-19.5	.0515V-23.0	.0434V-26.4	.0371V-30.0	.0322V-33.6	.0282V-37.2	.0250V-40.8
56	.0760V-16.1	.0609V-19.5	.0501V-22.9	.0422V-26.4	.0362V-29.9	.0314V-33.5	.0276V-37.1	.0244V-40.7
58	.0740V-16.1	.0592V-19.4	.0489V-22.9	.0411V-26.4	.0353V-29.8	.0307V-33.4	.0270V-37.0	.0239V-40.5
60	.0720V-16.0	.0577V-19.4	.0476V-22.8	.0402V-26.3	.0345V-29.8	.0300V-33.3	.0264V-36.9	.0234V-40.4
62	.0701V-16.0	.0562V-19.4	.0465V-22.8	.0393V-26.2	.0338V-29.8	.0294V-33.3	.0258V-36.8	.0229V-40.4
64	.0684V-15.9	.0550V-19.3	.0454V-22.8	.0384V-26.2	.0330V-29.7	.0287V-33.2	.0254V-36.8	.0225V-40.3
66	.0666V-15.9	.0536V-19.3	.0444V-22.7	.0375V-26.2	.0323V-29.6	.0282V-33.2	.0248V-36.7	.0221V-40.3
68	.0650V-15.9	.0524V-19.3	.0434V-22.6	.0367V-26.1	.0306V-29.6	.0276V-33.1	.0243V-36.6	.0216V-40.1

Developed from Volume Equation, $V = \frac{d}{162}(A_1 + 4M + A_2)$
where d = depth in feet, A_1 = top area (ft^2), M = median area (ft^2), and A_2 = bottom area (ft^2)

TABLE 9.4 (Cont.)

LENGTH DETERMINATION FOR EXCAVATED PITS

w	Depth of Pit (d), feet 5	6	7	8	9	10	11	12
70	.0636V-15.9	.0511V-19.3	.0424V-22.6	.0359V-26.1	.0309V-29.5	.0270V-33.0	.0238V-36.5	.0212V-40.0
72	.0621V-15.9	.0500V-19.2	.0415V-22.6	.0352V-26.0	.0303V-29.4	.0265V-32.9	.0234V-36.5	.0208V-40.0
74	.0607V-15.9	.0490V-19.2	.0406V-22.6	.0345V-26.0	.0297V-29.4	.0260V-32.9	.0228V-36.4	.0204V-39.9
76	.0594V-15.8	.0479V-19.2	.0398V-22.6	.0338V-25.9	.0292V-29.4	.0255V-32.8	.0225V-36.4	.0201V-39.9
78	.0581V-15.8	.0469V-19.1	.0390V-22.6	.0331V-25.9	.0286V-29.3	.0250V-32.8	.0221V-36.3	.0197V-39.8
80	.0569V-15.8	.0460V-19.1	.0383V-22.5	.0324V-25.8	.0280V-29.2	.0246V-32.8	.0217V-36.2	.0194V-39.8
82	.0557V-15.8	.0450V-19.1	.0374V-22.5	.0319V-25.8	.0276V-29.2	.0241V-32.7	.0214V-36.2	.0191V-39.7
84	.0545V-15.8	.0441V-19.0	.0368V-22.4	.0313V-25.8	.0270V-29.1	.0237V-32.6	.0210V-36.1	.0188V-39.6
86	.0535V-15.7	.0433V-19.0	.0361V-22.4	.0307V-25.8	.0266V-29.1	.0233V-32.6	.0206V-36.1	.0184V-39.6
88	.0525V-15.7	.0425V-19.0	.0354V-22.3	.0301V-25.7	.0261V-29.1	.0229V-32.6	.0202V-36.0	.0181V-39.5
90	.0515V-15.7	.0416V-19.0	.0348V-22.3	.0296V-25.7	.0256V-29.0	.0225V-32.5	.0199V-36.0	.0179V-39.5
92	.0505V-15.7	.0410V-19.0	.0342V-22.3	.0291V-25.7	.0252V-29.0	.0222V-32.5	.0196V-35.9	.0176V-39.4
94	.0495V-15.7	.0402V-19.0	.0336V-22.3	.0286V-25.6	.0248V-29.0	.0218V-32.4	.0193V-35.9	.0173V-39.3
96	.0486V-15.6	.0395V-18.9	.0330V-22.3	.0281V-25.6	.0244V-29.0	.0214V-32.4	.0190V-35.8	.0171V-39.3
98	.0478V-15.6	.0388V-18.9	.0324V-22.2	.0276V-25.6	.0240V-28.9	.0211V-32.4	.0187V-35.8	.0168V-39.2
100	.0470V-15.6	.0382V-18.9	.0319V-22.2	.0272V-25.6	.0236V-28.9	.0208V-32.3	.0184V-35.8	.0165V-39.2
102	.0461V-15.6	.0375V-18.9	.0314V-22.2	.0268V-25.5	.0233V-28.9	.0204V-32.3	.0182V-35.7	.0163V-39.2
104	.0454V-15.6	.0369V-18.9	.0308V-22.2	.0264V-25.5	.0229V-28.8	.0202V-32.3	.0179F-35.7	.0161V-39.1
106	.0446V-15.6	.0363V-18.9	.0304V-22.2	.0260V-25.5	.0226V-28.8	.0199V-32.2	.0177V-35.6	.0158V-39.1
108	.0439V-15.6	.0358V-18.9	.0299V-22.1	.0256V-25.4	.0222V-28.8	.0196V-32.2	.0174V-35.6	.0156V-39.0
110	.0432V-15.6	.0352V-18.9	.0294V-22.1	.0252V-25.4	.0219V-28.8	.0193V-32.2	.0171V-35.5	.0154V-39.0
112	.0425V-15.6	.0346V-18.8	.0290V-22.1	.0248V-25.4	.0216V-28.8	.0190V-32.1	.0169V-35.5	.0152V-39.0
114	.0419V-15.6	.0341V-18.8	.0286V-22.1	.0244V-25.4	.0213V-28.7	.0188V-32.1	.0167V-35.5	.0150V-38.9
116	.0413V-15.6	.0336V-18.8	.0282V-22.1	.0241V-25.4	.0210V-28.7	.0185V-32.0	.0165V-35.4	.0148V-38.8
118	.0406V-15.6	.0331V-18.8	.0278V-22.1	.0238V-25.4	.0207V-28.7	.0182V-32.0	.0163V-35.4	.0146V-38.8
120	.0400V-15.6	.0326V-18.8	.0274V-22.1	.0234V-25.3	.0204V-28.7	.0180V-32.0	.0160V-35.4	.0144V-38.8
122	.0394V-15.5	.0321V-18.8	.0270V-22.0	.0231V-25.3	.0201V-28.6	.0178V-32.0	.0158V-35.3	.0142V-38.7
124	.0388V-15.5	.0317V-18.8	.0266V-22.0	.0228V-25.3	.0199V-28.6	.0177V-31.9	.0156V-35.3	.0140V-38.7
126	.0383V-15.5	.0313V-18.8	.0262V-22.0	.0225V-25.3	.0196V-28.6	.0173V-31.9	.0154V-35.3	.0139V-38.7
128	.0378V-15.5	.0308V-18.7	.0259V-22.0	.0222V-25.3	.0194V-28.6	.0171V-31.9	.0152V-35.3	.0137V-38.6
130	.0372V-15.5	.0304V-18.7	.0255V-22.0	.0219V-25.2	.0191V-28.5	.0169V-31.9	.0151V-35.2	.0135V-38.6
132	.0367V-15.5	.0300V-18.7	.0252V-22.0	.0216V-25.2	.0189V-28.5	.0167V-31.9	.0149V-35.2	.0134V-38.6
134	.0362V-15.5	.0296V-18.7	.0249V-21.9	.0214V-25.2	.0186V-28.5	.0165V-31.8	.0147V-35.2	.0132V-38.5
136	.0358V-15.5	.0292V-18.7	.0246V-21.9	.0211V-25.2	.0184V-28.5	.0163V-31.8	.0145V-35.1	.0131V-38.5
138	.0353V-15.5	.0288V-18.7	.0243V-21.9	.0208V-25.2	.0182V-28.5	.0161V-31.8	.0144V-35.1	.0129V-38.5
140	.0348V-15.5	.0285V-18.7	.0240V-21.9	.0206V-25.2	.0180V-28.5	.0159V-31.8	.0142V-35.1	.0128V-38.5

TABLE 9.5

LENGTH DETERMINATION FOR EXCAVATED PITS

Sheet 1 of 2

$$1 = \frac{81V - 64d^3 - 12d^2w}{12d^2 + 3dw}$$

where: 1 = bottom length of the pit (feet)
V = volume in cubic yards
w = bottom width (feet)
d = depth of pit (feet)

Side Slopes 4:1
End Slopes 4:1

	Depth of Pit (d), feet							
w	5	6	7	8	9	10	11	12
20	.135V-23.3	.102V-28.4	.0804V-33.4	.0650V-38.6	.0535V-43.7	.0450V-48.9	.0384V-54.0	.0331V-59.2
22	.129V-23.2	.0979V-28.2	.0771V-33.2	.0625V-38.4	.0517V-43.5	.0435V-48.6	.0372V-53.8	.0322V-59.0
24	.123V-23.0	.0937V-28.0	.0741V-33.1	.0604V-38.1	.0500V-43.2	.0422V-48.3	.0361V-53.5	.0312V-58.7
26	.117V-22.9	.0900V-27.9	.0715V-32.8	.0583V-37.9	.0484V-43.0	.0409V-48.0	.0351V-53.2	.0304V-58.6
28	.113V-22.8	.0865V-27.7	.0689V-32.6	.0563V-37.7	.0469V-42.8	.0397V-47.8	.0341V-53.0	.0296V-58.1
30	.108V-22.7	.0834V-27.5	.0665V-32.5	.0545V-37.5	.0455V-42.6	.0386V-47.6	.0332V-52.8	.0288V-57.9
32	.104V-22.6	.0804V-27.4	.0644V-32.4	.0527V-37.4	.0441V-42.4	.0376V-47.5	.0323V-52.5	.0281V-57.7
34	.100V-22.5	.0776V-27.3	.0623V-32.2	.0512V-37.2	.0428V-42.2	.0365V-47.3	.0315V-52.3	.0274V-57.4
36	.0965V-22.4	.0750V-27.2	.0604V-32.1	.0496V-37.0	.0416V-42.0	.0356V-47.1	.0307V-52.0	.0268V-57.1
38	.0931V-22.3	.0726V-27.1	.0575V-32.0	.0483V-36.9	.0405V-41.9	.0346V-46.9	.0299V-51.9	.0262V-56.9
40	.0900V-22.2	.0704V-27.0	.0566V-31.8	.0469V-36.8	.0395V-41.7	.0338V-46.7	.0292V-51.7	.0256V-56.7
42	.0871V-22.2	.0682V-26.9	.0551V-31.7	.0456V-36.6	.0385V-41.6	.0330V-46.5	.0286V-51.5	.0250V-56.5
44	.0844V-22.1	.0662V-26.8	.0536V-31.6	.0445V-36.5	.0375V-41.4	.0322V-46.3	.0279V-51.4	.0245V-56.3
46	.0819V-22.0	.0644V-26.7	.0521V-31.5	.0433V-36.4	.0366V-41.3	.0314V-46.2	.0273V-51.3	.0240V-56.1
48	.0794V-22.0	.0635V-26.6	.0508V-31.4	.0422V-36.2	.0357V-41.1	.0307V-46.1	.0267V-51.1	.0234V-56.0
50	.0771V-21.9	.0609V-26.6	.0495V-31.4	.0411V-36.1	.0349V-41.0	.0300V-46.0	.0261V-50.9	.0230V-55.9
52	.0750V-21.8	.0592V-26.5	.0482V-31.3	.0402V-36.0	.0341V-40.9	.0296V-45.8	.0256V-50.7	.0225V-55.7
54	.0730V-21.8	.0577V-26.5	.0470V-31.2	.0392V-35.9	.0332V-40.8	.0288V-45.7	.0251V-50.6	.0221V-55.5
56	.0711V-21.8	.0562V-26.4	.0460V-31.1	.0384V-35.8	.0326V-40.7	.0282V-45.6	.0246V-50.5	.0216V-55.5
58	.0693V-21.7	.0550V-26.4	.0448V-31.0	.0375V-35.8	.0319V-40.6	.0276V-45.5	.0240V-50.4	.0212V-55.4
60	.0675V-21.6	.0536V-26.3	.0438V-31.0	.0367V-35.7	.0312V-40.5	.0270V-45.4	.0236V-50.2	.0208V-55.2
62	.0660V-21.6	.0524V-26.2	.0428V-30.9	.0359V-35.6	.0306V-40.4	.0265V-45.3	.0232V-50.1	.0204V-55.0
64	.0644V-21.6	.0511V-26.2	.0420V-30.8	.0352V-35.6	.0300V-40.3	.0260V-45.1	.0228V-50.0	.0201V-54.8
66	.0629V-21.6	.0500V-26.1	.0411V-30.8	.0345V-35.6	.0294V-40.2	.0255V-45.1	.0223V-49.9	.0197V-54.7
68	.0614V-21.5	.0490V-26.1	.0402V-30.7	.0338V-35.5	.0288V-40.1	.0250V-45.0	.0219V-49.8	.0194V-54.6

Developed from Volume Equation, $V = \frac{d}{162} (A_1 + 4M + A_2)$
where d = depth in feet, A_1 = top area (ft^2), M = median area (ft^2), and A_2 = bottom area (ft^2)

TABLE 9.5 (Cont.)

LENGTH DETERMINATION FOR EXCAVATED PITS

Sheet 2 of 2

w	Depth of Pit (d), feet 5	6	7	8	9	10	11	12
70	.0600V-21.5	.0479V-26.1	.0393V-30.7	.0331V-35.4	.0283V-40.0	.0246V-44.9	.0216V-49.6	.0191V-54.5
72	.0587V-21.4	.0469V-26.0	.0386V-30.6	.0324V-35.3	.0278V-40.0	.0241V-44.8	.0212V-49.5	.0188V-54.4
74	.0575V-21.4	.0460V-26.0	.0378V-30.6	.0318V-35.2	.0273V-39.9	.0237V-44.7	.0208V-49.5	.0185V-54.3
76	.0562V-21.4	.0450V-25.9	.0371V-30.5	.0313V-35.1	.0268V-39.8	.0233V-44.6	.0204V-49.4	.0182V-54.2
78	.0551V-21.4	.0441V-25.9	.0364V-30.4	.0307V-35.1	.0263V-39.8	.0229V-44.5	.0201V-49.3	.0179V-54.1
80	.0540V-21.3	.0433V-25.9	.0357V-30.4	.0301V-35.0	.0258V-39.7	.0225V-44.5	.0198V-49.2	.0176V-54.0
82	.0530V-21.3	.0425V-25.8	.0351V-30.4	.0296V-35.0	.0254V-39.7	.0221V-44.4	.0195V-49.1	.0173V-54.0
84	.0519V-21.3	.0416V-25.8	.0345V-30.3	.0291V-35.0	.0250V-39.7	.0218V-44.3	.0192V-49.0	.0170V-53.9
86	.0510V-21.3	.0410V-25.8	.0338V-30.3	.0286V-34.9	.0246V-39.6	.0214V-44.2	.0189V-49.0	.0168V-53.8
88	.0500V-21.2	.0402V-25.8	.0332V-30.3	.0281V-34.9	.0242V-39.5	.0211V-44.1	.0186V-48.9	.0166V-53.7
90	.0491V-21.2	.0395V-25.7	.0327V-30.2	.0275V-34.8	.0238V-39.5	.0208V-44.1	.0183V-48.8	.0163V-53.5
92	.0482V-21.2	.0388V-25.7	.0322V-30.2	.0272V-34.8	.0234V-39.4	.0204V-44.0	.0181V-48.7	.0161V-53.5
94	.0474V-21.2	.0381V-25.7	.0316V-30.2	.0268V-34.7	.0231V-39.4	.0202V-44.0	.0178V-48.6	.0159V-53.4
96	.0466V-21.2	.0375V-25.7	.0311V-30.1	.0264V-34.7	.0228V-39.3	.0199V-43.9	.0175V-48.6	.0156V-53.4
98	.0458V-21.1	.0369V-25.7	.0306V-30.1	.0260V-34.6	.0224V-39.3	.0196V-43.9	.0173V-48.5	.0154V-53.3
100	.0450V-21.1	.0363V-25.6	.0301V-30.1	.0256V-34.6	.0221V-39.2	.0193V-43.8	.0170V-48.5	.0152V-53.3
102	.0443V-21.1	.0357V-25.6	.0297V-30.1	.0252V-34.6	.0218V-39.2	.0190V-43.8	.0168V-48.4	.0150V-53.2
104	.0436V-21.0	.0352V-25.6	.0292V-30.0	.0248V-34.6	.0214V-39.1	.0188V-43.7	.0166V-48.4	.0148V-53.1
106	.0429V-21.0	.0346V-25.5	.0288V-30.0	.0244V-34.5	.0211V-39.1	.0185V-43.6	.0164V-48.3	.0146V-53.1
108	.0421V-21.0	.0341V-25.5	.0284V-30.0	.0241V-34.5	.0208V-39.0	.0182V-43.6	.0161V-48.3	.0144V-53.0
110	.0416V-21.0	.0336V-25.5	.0280V-30.0	.0238V-34.5	.0206V-39.0	.0180V-43.5	.0159V-48.2	.0142V-52.9
112	.0409V-21.0	.0331V-25.4	.0276V-29.9	.0234V-34.4	.0203V-39.0	.0178V-43.5	.0157V-48.2	.0141V-52.8
114	.0404V-21.0	.0326V-25.4	.0272V-29.9	.0232V-34.4	.0200V-38.9	.0175V-43.5	.0155V-48.2	.0139V-52.7
116	.0397V-21.0	.0321V-25.4	.0268V-29.9	.0228V-34.4	.0197V-38.9	.0173V-43.4	.0153V-48.1	.0137V-52.6
118	.0392V-21.0	.0317V-25.4	.0264V-29.9	.0225V-34.3	.0195V-38.9	.0171V-43.4	.0152V-48.1	.0136V-52.6
120	.0386V-21.0	.0312V-25.4	.0261V-29.9	.0222V-34.3	.0192V-38.8	.0169V-43.4	.0150V-48.1	.0134V-52.6
122	.0380V-20.9	.0310V-25.3	.0257V-29.7	.0219V-34.2	.0190V-38.7	.0167V-43.3	.0148V-47.9	.0132V-52.5
124	.0375V-20.9	.0304V-25.3	.0254V-29.7	.0216V-34.2	.0188V-38.7	.0165V-43.3	.0146V-47.8	.0131V-52.5
126	.0370V-20.9	.0300V-25.3	.0250V-29.7	.0214V-34.2	.0185V-38.7	.0163V-43.2	.0144V-47.8	.0129V-52.4
128	.0365V-20.9	.0296V-25.3	.0247V-29.7	.0211V-34.1	.0183V-38.6	.0161V-43.2	.0143V-47.8	.0128V-52.4
130	.0360V-20.9	.0292V-25.2	.0244V-29.7	.0208V-34.1	.0181V-38.6	.0159V-43.1	.0141V-47.7	.0126V-52.3
132	.0355V-20.9	.0288V-25.2	.0241V-29.6	.0206V-34.1	.0179V-38.6	.0157V-43.1	.0139V-47.7	.0125V-52.3
134	.0350V-20.9	.0285V-25.2	.0238V-29.6	.0203V-34.1	.0176V-38.5	.0155V-43.1	.0138V-47.6	.0124V-52.2
136	.0346V-20.9	.0281V-25.2	.0235V-29.6	.0201V-34.0	.0174V-38.5	.0153V-43.0	.0136V-47.6	.0122V-52.2
138	.0342V-20.8	.0278V-25.2	.0232V-29.6	.0199V-34.0	.0172V-38.5	.0152V-43.0	.0135V-47.5	.0121V-52.1
140	.0338V-20.8	.0274V-25.2	.0230V-29.6	.0196V-34.0	.0170V-38.5	.0150V-43.0	.0133V-47.5	.0120V-52.0

TABLE 9.6

LENGTH DETERMINATION FOR EXCAVATED PITS

$$l = \frac{81V - 32d^3 - 12d^2w}{6d^2 + 3dw}$$

where: l = bottom length of the pit (feet)
V = volume in cubic yards
w = bottom width (feet)
d = depth of pit (feet)

Side Slopes 2:1
End Slopes 4:1

w	Depth of Pit (d), feet 5	6	7	8	9	10	11	12
20	.180V-22.2	.141V-27.0	.114V-31.8	.0938V-36.7	.0789V-41.7	.0675V-46.7	.0584V-51.7	.0511V-56.7
22	.169V-22.1	.132V-26.8	.107V-31.6	.0888V-36.3	.0751V-41.2	.0644V-46.4	.0558V-51.3	.0490V-56.3
24	.159V-22.0	.125V-26.8	.102V-31.5	.0843V-36.1	.0718V-41.0	.0614V-46.1	.0534V-51.0	.0470V-56.0
26	.150V-21.8	.119V-26.6	.0965V-31.2	.0809V-35.9	.0682V-40.9	.0587V-45.8	.0512V-50.8	.0450V-55.8
28	.142V-21.7	.113V-26.6	.0919V-31.1	.0772V-35.8	.0653V-40.7	.0563V-45.5	.0491V-50.5	.0434V-55.5
30	.135V-21.6	.107V-26.4	.0876V-31.0	.0738V-35.7	.0625V-40.5	.0540V-45.3	.0472V-50.1	.0417V-55.1
32	.129V-21.6	.102V-26.2	.0839V-30.9	.0707V-35.5	.0600V-40.3	.0520V-45.1	.0455V-49.9	.0402V-54.9
34	.123V-21.5	.0978V-26.1	.0804V-30.8	.0678V-35.4	.0576V-40.2	.0500V-45.0	.0438V-49.8	.0388V-54.7
36	.117V-21.4	.0937V-26.0	.0771V-30.6	.065V-35.3	.0554V-40.1	.0483V-44.7	.0424V-49.6	.0375V-54.5
38	.113V-21.4	.0900V-25.9	.0741V-30.5	.0625V-35.2	.0535V-40.0	.0466V-44.6	.0409V-49.4	.0363V-54.3
40	.108V-21.3	.0865V-25.9	.0715V-30.4	.0603V-35.0	.0517V-39.7	.045V-44.4	.0396V-49.2	.0352V-54.0
42	.104V-21.3	.0834V-25.8	.0689V-30.4	.0581V-34.9	.0500V-39.6	.0435V-44.4	.0384V-49.1	.0342V-53.8
44	.100V-21.2	.0804V-25.7	.0665V-30.3	.056V-34.8	.0484V-39.5	.0422V-44.2	.0372V-48.9	.0332V-53.6
46	.0965V-21.2	.0776V-25.6	.0644V-30.2	.0542V-34.7	.0469V-39.4	.0409V-44.1	.0361V-48.8	.0322V-53.5
48	.0931V-21.2	.0750V-25.6	.0623V-30.1	.0526V-34.7	.0455V-39.2	.0397V-43.9	.0351V-48.6	.0313V-53.4
50	.0900V-21.1	.0726V-25.6	.0604V-30.1	.051V-34.6	.0441V-39.2	.0386V-43.8	.0341V-48.5	.0304V-53.2
52	.0871V-21.1	.0704V-25.6	.0585V-30.0	.0496V-34.5	.0428V-39.1	.0376V-43.6	.0332V-48.4	.0296V-53.0
54	.0844V-21.0	.0682V-25.5	.0566V-30.0	.0482V-34.5	.0416V-39.0	.0365V-43.5	.0323V-48.2	.0289V-52.9
56	.0819V-21.0	.0662V-25.4	.0551V-29.9	.0469V-34.4	.0405V-38.9	.0356V-43.5	.0315V-48.0	.0282V-52.8
58	.0794V-21.0	.0644V-25.4	.0536V-29.8	.047V-34.3	.0395V-38.8	.0346V-43.4	.0307V-48.0	.0275V-52.7
60	.0771V-21.0	.0635V-25.4	.0521V-29.8	.0444V-34.2	.0385V-38.8	.0338V-43.3	.0299V-47.7	.0268V-52.6
62	.0750V-20.9	.0609V-25.4	.0507V-29.8	.0432V-34.2	.0375V-38.7	.0330V-43.3	.0292V-47.8	.0262V-52.5
64	.0730V-20.9	.0592V-25.3	.0495V-29.7	.0421V-34.1	.0366V-38.6	.0322V-43.2	.0286V-47.7	.0256V-52.4
66	.0711V-20.9	.0577V-25.2	.0482V-29.6	.0412V-34.1	.0357V-38.6	.0314V-43.1	.0279V-47.6	.0250V-52.3
68	.0693V-20.8	.0562V-25.2	.0471V-29.6	.0402V-34.0	.0349V-38.5	.0307V-43.0	.0273V-47.5	.0244V-52.2

Developed from Volume Equation, $V = \frac{d}{162}(A_1 + 4M + A_2)$
where d = depth in feet, A_1 = top area (ft^2), M = median area (ft^2), and A_2 = bottom area (ft^2)

TABLE 9.6 (Cont.)

LENGTH DETERMINATION FOR EXCAVATED PITS

Sheet 2 of 2

w	Depth of Pit (d), feet 5	6	7	8	9	10	11	12
70	.0675V-20.8	.0550V-25.2	.0460V-29.6	.0393V-34.0	.0341V-38.5	.0300V-43.0	.0267V-47.5	.0240V-52.0
72	.0660V-20.8	.0536V-25.1	.0448V-29.5	.0384V-34.0	.0332V-38.4	.0296V-42.9	.0261V-47.4	.0234V-52.0
74	.0644V-20.8	.0524V-25.1	.0439V-29.5	.0376V-33.9	.0326V-38.4	.0288V-42.8	.0256V-47.4	.0230V-51.9
76	.0629V-20.8	.0511V-25.1	.0429V-29.5	.0367V-33.8	.0319V-38.4	.0282V-42.7	.0251V-47.3	.0225V-51.8
78	.0614V-20.7	.0500V-25.0	.0420V-29.5	.0359V-33.8	.0312V-38.2	.0276V-42.7	.0246V-47.3	.0221V-51.7
80	.0600V-20.7	.0490V-25.0	.0410V-29.4	.0352V-33.7	.0306V-38.2	.0270V-42.7	.0240V-47.2	.0216V-51.6
82	.0587V-20.7	.0479V-25.0	.0402V-29.4	.0345V-33.7	.0300V-38.2	.0265V-42.6	.0236V-47.1	.0212V-51.5
84	.0575V-20.7	.0469V-25.0	.0394V-29.4	.0338V-33.7	.0294V-38.2	.0260V-42.5	.0232V-47.1	.0208V-51.5
86	.0562V-20.7	.0460V-25.0	.0386V-29.4	.0331V-33.7	.0288V-38.1	.0255V-42.5	.0228V-47.1	.0205V-51.5
88	.0551V-20.7	.0450V-25.0	.0378V-29.3	.0324V-33.6	.0283V-38.0	.0250V-42.5	.0223V-46.9	.0201V-51.5
90	.0540V-20.6	.0441V-25.0	.0371V-29.3	.0318V-33.6	.0278V-38.0	.0246V-42.5	.0219V-46.9	.0197V-51.4
92	.0530V-20.6	.0433V-25.0	.0364V-29.3	.0313V-33.5	.0273V-38.0	.0241V-42.5	.0216V-46.8	.0194V-51.3
94	.0519V-20.6	.0425V-24.9	.0357V-29.2	.0307V-33.5	.0268V-37.9	.0237V-42.4	.0212V-46.8	.0190V-51.2
96	.0509V-20.6	.0416V-24.9	.0351V-29.2	.0301V-33.5	.0263V-37.9	.0233V-42.4	.0208V-46.7	.0187V-51.1
98	.0500V-20.6	.0410V-24.9	.0345V-29.2	.0296V-33.5	.0258V-37.8	.0229V-42.3	.0204V-46.7	.0185V-51.0
100	.0491V-20.6	.0402V-24.9	.0339V-29.2	.0291V-33.5	.0254V-37.8	.0225V-42.2	.0201V-46.6	.0182V-51.0
102	.0482V-20.6	.0395V-24.8	.0332V-29.2	.0286V-33.5	.0250V-37.8	.0222V-42.1	.0198V-46.6	.0179V-51.0
104	.0474V-20.6	.0388V-24.8	.0327V-29.1	.0282V-33.4	.0248V-37.8	.0218V-42.1	.0195V-46.6	.0176V-51.0
106	.0466V-20.6	.0381V-24.8	.0322V-29.1	.0277V-33.4	.0242V-37.7	.0214V-42.1	.0192V-46.5	.0173V-51.0
108	.0458V-20.6	.0375V-24.8	.0316V-29.1	.0272V-33.4	.0238V-37.7	.0211V-42.0	.0189V-46.5	.0171V-51.0
110	.0450V-20.6	.0369V-24.8	.0312V-29.1	.0268V-33.4	.0234V-37.7	.0208V-42.0	.0186V-46.5	.0168V-50.9
112	.0443V-20.5	.0363V-24.8	.0306V-29.0	.0264V-33.3	.0231V-37.6	.0222V-42.0	.0183V-46.5	.0166V-50.9
114	.0436V-20.5	.0357V-24.8	.0301V-29.0	.0260V-33.3	.0227V-37.6	.0202V-42.0	.0181V-46.5	.0163V-50.8
116	.0429V-20.5	.0352V-24.8	.0297V-29.0	.0256V-33.3	.0224V-37.6	.0199V-42.0	.0178V-46.5	.0161V-50.8
118	.0422V-20.5	.0346V-24.8	.0292V-29.0	.0252V-33.3	.0220V-37.6	.0196V-42.0	.0175V-46.4	.0159V-50.7
120	.0416V-20.5	.0341V-24.8	.0288V-29.0	.0248V-33.3	.0217V-37.6	.0193V-42.0	.0173V-46.4	.0156V-50.6
122	.0409V-20.5	.0336V-24.7	.0284V-29.0	.0245V-33.2	.0214V-37.5	.0190V-41.9	.0170V-46.2	.0154V-50.6
124	.0403V-20.5	.0331V-24.7	.0280V-28.9	.0241V-33.2	.0211V-37.5	.0188V-41.9	.0168V-46.2	.0152V-50.6
126	.0400V-20.5	.0326V-24.7	.0276V-28.9	.0238V-33.2	.0208V-37.5	.0185V-41.8	.0166V-46.2	.0150V-50.6
128	.0391V-20.5	.0321V-24.7	.0272V-28.9	.0234V-33.2	.0205V-37.5	.0182V-41.8	.0164V-46.2	.0148V-50.5
130	.0386V-20.5	.0317V-24.7	.0268V-28.9	.0231V-33.2	.0203V-37.5	.0180V-41.8	.0161V-46.1	.0146V-50.5
132	.0380V-20.5	.0313V-24.7	.0264V-28.9	.0228V-33.2	.0200V-37.4	.0178V-41.8	.0159V-46.1	.0144V-50.5
134	.0375V-20.5	.0308V-24.7	.0261V-28.9	.0225V-33.1	.0197V-37.4	.0175V-41.7	.0157V-46.1	.0142V-50.4
136	.0370V-20.5	.0304V-24.6	.0257V-28.9	.0222V-33.1	.0194V-37.4	.0173V-41.7	.0155V-46.0	.0141V-50.4
138	.0365V-20.5	.0300V-24.6	.0254V-28.8	.0219V-33.1	.0192V-37.4	.0171V-41.7	.0153V-46.0	.0139V-50.4
140	.0360V-20.4	.0296V-24.6	.0250V-28.8	.0216V-33.1	.0190V-37.4	.0168V-41.7	.0152V-46.0	.0137V-50.3

TABLE 9.7

LENGTH DETERMINATION FOR EXCAVATED PITS

$$l = \frac{27V - 16d^3 - 4d^2w}{3d^2 + dw}$$

Sheet 1 of 1

where: l = bottom length of the pit (feet)
V = volume in cubic yards
w = bottom width (feet)
d - depth of pit (feet)

Side Slopes 3:1
End Slopes 4:1

w	Depth of Pit (d), feet							
	5	6	7	8	9	10	11	12
20	.154V-22.8	.118V-27.8	.0941V-32.8	.0768V-37.8	.0639V-42.8	.0540V-48.0	.0464V-53.0	.0402V-58.2
22	.146V-22.7	.113V-27.6	.0894V-32.6	.0735V-37.5	.0613V-42.6	.0520V-47.6	.0446V-52.8	.0388V-58.0
24	.139V-22.6	.107V-27.5	.0854V-32.4	.0704V-37.3	.0589V-42.4	.0500V-47.4	.0431V-52.5	.0375V-57.7
26	.132V-22.4	.102V-27.3	.0818V-32.2	.0675V-37.2	.0566V-42.1	.0482V-47.1	.0416V-52.2	.0363V-57.4
28	.126V-22.3	.0979V-27.2	.0775V-32.0	.0650V-37.0	.0545V-42.0	.0466V-46.9	.0403V-51.9	.0352V-57.1
30	.120V-22.2	.0937V-27.0	.0756V-31.8	.0625V-36.8	.0526V-41.8	.0450V-46.6	.0390V-51.6	.0341V-56.8
32	.115V-22.2	.0900V-26.9	.0728V-31.7	.0604V-36.6	.0510V-41.5	.0436V-46.4	.0378V-51.4	.0331V-56.5
34	.110V-22.1	.0865V-26.8	.0701V-31.6	.0582V-36.4	.0492V-41.3	.0422V-46.2	.0366V-51.2	.0322V-56.3
36	.106V-22.0	.0834V-26.7	.0676V-31.4	.0563V-36.2	.0476V-41.1	.0409V-46.0	.0356V-51.0	.0312V-56.0
38	.102V-21.9	.0804V-26.6	.0655V-31.3	.0545V-36.1	.0462V-41.0	.0398V-45.9	.0346V-50.8	.0304V-55.8
40	.0982V-21.8	.0776V-26.5	.0632V-31.2	.0528V-36.0	.0448V-40.9	.0386V-45.7	.0337V-50.6	.0296V-55.6
42	.0946V-21.8	.0750V-26.4	.0611V-31.1	.0512V-35.8	.0435V-40.7	.0375V-45.5	.0328V-50.5	.0288V-55.4
44	.0916V-21.7	.0726V-26.3	.0595V-31.0	.0496V-35.7	.0423V-40.5	.0367V-45.4	.0319V-50.3	.0282V-55.2
46	.0885V-21.6	.0704V-26.2	.0576V-31.0	.0483V-35.6	.0411V-40.4	.0356V-45.3	.0311V-50.1	.0274V-55.0
48	.0857V-21.6	.0682V-26.2	.0560V-30.9	.0469V-35.5	.0400V-40.3	.0346V-45.1	.0303V-50.0	.0268V-54.8
50	.0830V-21.6	.0662V-26.1	.0543V-30.8	.0456V-35.4	.0390V-40.2	.0338V-45.0	.0296V-49.9	.0262V-54.7
52	.0806V-21.5	.0644V-26.1	.0528V-30.7	.0454V-35.4	.0380V-40.1	.0330V-44.9	.0289V-49.8	.0256V-54.5
54	.0783V-21.5	.0635V-26.0	.0515V-30.6	.0434V-35.3	.0371V-40.0	.0322V-44.8	.0282V-49.6	.0250V-54.4
56	.0760V-21.4	.0609V-26.0	.0501V-30.6	.0422V-35.2	.0362V-39.9	.0314V-44.7	.0276V-49.4	.0244V-54.3
58	.0740V-21.4	.0592V-25.9	.0489V-30.5	.0411V-35.1	.0353V-39.9	.0307V-44.6	.0270V-49.3	.0239V-54.1
60	.0720V-21.3	.0577V-25.8	.0476V-30.4	.0402V-35.0	.0345V-39.8	.0300V-44.5	.0264V-49.2	.0234V-54.0
62	.0701V-21.3	.0562V-25.8	.0465V-30.4	.0393V-35.0	.0338V-39.7	.0294V-44.4	.0258V-49.1	.0229V-53.9
64	.0684V-21.2	.0550V-25.8	.0454V-30.3	.0384V-34.9	.0330V-39.6	.0287V-44.3	.0254V-49.0	.0225V-53.8
66	.0666V-21.2	.0536V-25.7	.0444V-30.2	.0375V-34.8	.0323V-39.5	.0282V-44.2	.0248V-48.9	.0221V-53.7
68	.0650V-21.2	.0524V-25.7	.0434V-30.2	.0367V-34.8	.0316V-39.4	.0276V-44.1	.0243V-48.8	.0216V-53.6

Developed from Volume Equation, $V = \frac{d}{162}(A_1 + 4M + A_2)$
where d = depth in feet, A_1 = top area (ft^2), M = median area (ft^2), and A_2 = bottom area (ft^2)

TABLE 9.7

LENGTH DETERMINATION FOR EXCAVATED PITS

$$l = \frac{27V - 16d^3 - 4d^2w}{3d^2 + dw}$$

Sheet 1 of 1

where: l = bottom length of the pit (feet)
V = volume in cubic yards
w = bottom width (feet)
d - depth of pit (feet)

Side Slopes 3:1
End Slopes 4:1

w	Depth of Pit (d), feet 5	6	7	8	9	10	11	12
20	.154V-22.8	.118V-27.8	.0941V-32.8	.0768V-37.8	.0639V-42.8	.0540V-48.0	.0464V-53.0	.0402V-58.2
22	.146V-22.7	.113V-27.6	.0894V-32.6	.0735V-37.5	.0613V-42.6	.0520V-47.6	.0446V-52.8	.0388V-58.0
24	.139V-22.6	.107V-27.5	.0854V-32.4	.0704V-37.3	.0589V-42.4	.0500V-47.4	.0431V-52.5	.0375V-57.7
26	.132V-22.4	.102V-27.3	.0818V-32.2	.0675V-37.2	.0566V-42.1	.0482V-47.1	.0416V-52.2	.0363V-57.4
28	.126V-22.3	.0979V-27.2	.0775V-32.0	.0650V-37.0	.0545V-42.0	.0466V-46.9	.0403V-51.9	.0352V-57.1
30	.120V-22.2	.0937V-27.0	.0756V-31.8	.0625V-36.8	.0526V-41.8	.0450V-46.6	.0390V-51.6	.0341V-56.8
32	.115V-22.2	.0900V-26.9	.0728V-31.7	.0604V-36.6	.0510V-41.5	.0436V-46.4	.0378V-51.4	.0331V-56.5
34	.110V-22.1	.0865V-26.8	.0701V-31.6	.0582V-36.4	.0492V-41.3	.0422V-46.2	.0366V-51.2	.0322V-56.3
36	.106V-22.0	.0834V-26.7	.0676V-31.4	.0563V-36.2	.0476V-41.1	.0409V-46.0	.0356V-51.0	.0312V-56.0
38	.102V-21.9	.0804V-26.6	.0655V-31.3	.0545V-36.1	.0462V-41.0	.0398V-45.9	.0346V-50.8	.0304V-55.8
40	.0982V-21.8	.0776V-26.5	.0632V-31.2	.0528V-36.0	.0448V-40.9	.0386V-45.7	.0337V-50.6	.0296V-55.6
42	.0946V-21.8	.0750V-26.4	.0611V-31.1	.0512V-35.8	.0435V-40.7	.0375V-45.5	.0328V-50.5	.0288V-55.4
44	.0916V-21.7	.0726V-26.3	.0595V-31.0	.0496V-35.7	.0423V-40.5	.0367V-45.4	.0319V-50.3	.0282V-55.2
46	.0885V-21.6	.0704V-26.2	.0576V-31.0	.0483V-35.6	.0411V-40.4	.0356V-45.3	.0311V-50.1	.0274V-55.0
48	.0857V-21.6	.0682V-26.2	.0560V-30.9	.0469V-35.5	.0400V-40.3	.0346V-45.1	.0303V-50.0	.0268V-54.8
50	.0830V-21.6	.0662V-26.1	.0543V-30.8	.0456V-35.4	.0390V-40.2	.0338V-45.0	.0296V-49.9	.0262V-54.7
52	.0806V-21.5	.0644V-26.1	.0528V-30.7	.0454V-35.4	.0380V-40.1	.0330V-44.9	.0289V-49.8	.0256V-54.5
54	.0783V-21.5	.0635V-26.0	.0515V-30.6	.0434V-35.3	.0371V-40.0	.0322V-44.8	.0282V-49.6	.0250V-54.4
56	.0760V-21.4	.0609V-26.0	.0501V-30.6	.0422V-35.2	.0362V-39.9	.0314V-44.7	.0276V-49.4	.0244V-54.3
58	.0740V-21.4	.0592V-25.9	.0489V-30.5	.0411V-35.1	.0353V-39.9	.0307V-44.6	.0270V-49.3	.0239V-54.1
60	.0720V-21.3	.0577V-25.8	.0476V-30.4	.0402V-35.0	.0345V-39.8	.0300V-44.5	.0264V-49.2	.0234V-54.0
62	.0701V-21.3	.0562V-25.8	.0465V-30.4	.0393V-35.0	.0338V-39.7	.0294V-44.4	.0258V-49.1	.0229V-53.9
64	.0684V-21.2	.0550V-25.8	.0454V-30.3	.0384V-34.9	.0330V-39.6	.0287V-44.3	.0254V-49.0	.0225V-53.8
66	.0666V-21.2	.0536V-25.7	.0444V-30.2	.0375V-34.8	.0323V-39.5	.0282V-44.2	.0248V-48.9	.0221V-53.7
68	.0650V-21.2	.0524V-25.7	.0434V-30.2	.0367V-34.8	.0316V-39.4	.0276V-44.1	.0243V-48.8	.0216V-53.6

Developed from Volume Equation, $V = \frac{d}{162}(A_1 + 4M + A_2)$
where d = depth in feet, A_1 = top area (ft^2), M = median area (ft^2), and A_2 = bottom area (ft^2)

TABLE 9.8

LENGTH DETERMINATION FOR EXCAVATED PITS

$$l = \frac{27V - 20d^3 - 5d^2w}{3d^2 + dw}$$

where: l = bottom length of the pit (feet)
V = volume, in cubic yards
w = bottom width (feet)
d = depth of pit (feet)

Side Slopes 3:1
End Slopes 6:1 - 4:1

w	Depth of Pit (d), feet 5	6	7	8	9	10	11	12
20	.1543V-28.6	.1184V-34.7	.1011V-44.0	.0767V-47.3	.0638V-53.6	.0540V-60.0	.0463V-66.4	.0402V-72.9
22	.1459V-28.4	.1125V-34.5	.0968V-43.9	.0734V-47.0	.0612V-53.2	.0519V-59.6	.0446V-66.0	.0388V-72.4
24	.1385V-28.2	.1071V-34.3	.0928V-43.8	.0703V-46.7	.0588V-52.9	.0500V-59.3	.0431V-65.4	.0375V-72.0
26	.1317V-28.0	.1028V-34.1	.0891V-43.7	.0675V-46.4	.0566V-52.6	.0482V-58.9	.0416V-65.2	.0363V-71.6
28	.1256V-27.9	.0978V-33.9	.0857V-43.6	.0649V-46.2	.0545V-52.4	.0466V-58.6	.0402V-64.9	.0352V-71.3
30	.1200V-27.8	.0938V-33.8	.0826V-43.5	.0625V-45.9	.0526V-52.1	.0450V-58.3	.0389V-64.6	.0341V-70.9
32	.1149V-27.7	.0900V-33.6	.0796V-43.4	.0603V-45.7	.0508V-51.9	.0435V-58.1	.0378V-64.3	.0331V-70.6
34	.1102V-27.6	.0865V-33.5	.0792V-43.3	.0582V-45.5	.0492V-51.6	.0420V-57.8	.0366V-64.0	.0321V-70.3
36	.1059V-27.5	.0833V-33.3	.0744V-43.2	.0563V-45.3	.0476V-51.4	.0409V-57.6	.0356V-63.8	.0313V-70.0
38	.1019V-27.4	.0804V-33.2	.0720V-43.1	.0544V-45.2	.0462V-51.2	.0397V-57.4	.0346V-63.5	.0304V-69.7
40	.0982V-27.3	.0776V-33.1	.0698V-43.0	.0527V-45.0	.0448V-51.0	.0386V-57.1	.0336V-63.3	.0296V-69.5
42	.0947V-27.2	.0750V-33.0	.0677V-43.0	.0511V-44.8	.0435V-50.9	.0375V-56.9	.0328V-63.1	.0288V-69.2
44	.0915V-27.1	.0726V-32.9	.0657V-42.9	.0496V-44.7	.0423V-50.7	.0365V-56.8	.0319V-62.9	.0281V-69.0
46	.0885V-27.0	.0703V-32.8	.0638V-42.9	.0482V-44.5	.0411V-50.5	.0355V-56.6	.0311V-62.6	.0274V-68.8
48	.0857V-27.0	.0682V-32.7	.0621V-42.8	.0469V-44.4	.0400V-50.4	.0346V-56.4	.0303V-62.5	.0268V-68.6
50	.0831V-26.9	.0662V-32.6	.0604V-42.8	.0456V-44.3	.0390V-50.3	.0338V-56.3	.0296V-62.3	.0262V-68.4
52	.0806V-26.9	.0643V-32.6	.0588V-42.7	.0444V-44.2	.0380V-50.1	.0329V-56.1	.0289V-62.1	.0256V-68.2
54	.0783V-26.8	.0625V-32.5	.0573V-42.7	.0433V-44.1	.0370V-50.0	.0321V-56.0	.0282V-62.0	.0250V-68.0
56	.0761V-26.8	.0608V-32.4	.0559V-42.6	.0422V-44.0	.0360V-49.9	.0314V-55.8	.0276V-61.8	.0245V-67.8
58	.0740V-26.7	.0592V-32.4	.0545V-42.6	.0412V-43.9	.0353V-49.8	.0307V-55.7	.0270V-61.6	.0239V-67.7
60	.0720V-26.7	.0577V-32.3	.0533V-42.5	.0402V-43.8	.0345V-49.7	.0300V-55.6	.0264V-61.5	.0234V-67.5
62	.0701V-26.6	.0563V-32.3	.0520V-42.5	.0392V-43.7	.0337V-49.6	.0293V-55.4	.0258V-61.4	.0230V-67.3
64	.0684V-26.6	.0549V-32.2	.0508V-42.4	.0383V-43.6	.0330V-49.5	.0287V-55.3	.0253V-61.2	.0225V-67.2
66	.0667V-26.5	.0536V-32.1	.0497V-42.4	.0375V-43.6	.0323V-49.4	.0281V-55.2	.0248V-61.1	.0221V-67.1
68	.0651V-26.5	.0523V-32.1	.0486V-42.4	.0367V-43.5	.0316V-49.3	.0276V-55.1	.0243V-61.0	.0216V-66.9

Developed from Volume Equation, $V = \frac{d}{162}(A_1 + 4M + A_2)$
where d = depth in feet, A_1 = top area (ft^2), M = median area (ft^2), and A_2 = bottom area (ft^2)

TABLE 9.8 (Cont.)

LENGTH DETERMINATION FOR EXCAVATED PITS

w	Depth of Pit (d), feet 5	6	7	8	9	10	11	12
70	.0667V-26.5	.0511V-32.0	.0476V-42.3	.0359V-43.4	.0309V-49.2	.0270V-55.0	.0238V-60.9	.0212V-66.8
72	.0635V-26.4	.0500V-32.0	.0466V-42.3	.0351V-43.3	.0303V-49.1	.0265V-54.9	.0234V-60.8	.0208V-66.7
74	.0607V-26.4	.0489V-32.0	.0457V-42.3	.0344V-43.3	.0297V-49.0	.0260V-54.8	.0229V-60.6	.0205V-66.5
76	.0593V-26.4	.0479V-31.9	.0448V-42.3	.0338V-43.2	.0291V-48.9	.0255V-54.7	.0225V-60.6	.0201V-66.4
78	.0581V-26.3	.0469V-31.9	.0439V-42.2	.0331V-43.1	.0286V-48.9	.0250V-54.6	.0221V-60.5	.0197V-66.3
80	.0568V-26.3	.0459V-31.8	.0430V-42.2	.0325V-43.1	.0280V-48.8	.0245V-54.5	.0217V-60.4	.0194V-66.2
82	.0557V-26.3	.0450V-31.8	.0423V-42.2	.0318V-43.0	.0275V-48.7	.0241V-54.5	.0213V-60.3	.0191V-66.1
84	.0545V-26.3	.0441V-31.8	.0415V-42.2	.0313V-43.0	.0270V-48.6	.0237V-54.4	.0210V-60.2	.0188V-66.0
86	.0535V-26.2	.0433V-31.7	.0407V-42.1	.0307V-42.9	.0265V-48.6	.0233V-54.3	.0206V-60.1	.0184V-65.9
88	.0524V-26.2	.0426V-31.7	.0400V-42.1	.0301V-42.9	.0261V-48.5	.0229V-54.2	.0203V-60.0	.0181V-65.8
90	.0514V-26.2	.0417V-31.7	.0393V-42.1	.0296V-42.8	.0256V-48.5	.0225V-54.2	.0200V-59.9	.0179V-65.7
92	.0505V-26.2	.0409V-31.6	.0386V-42.1	.0291V-42.8	.0252V-48.4	.0221V-54.1	.0196V-59.8	.0176V-65.6
94	.0495V-26.1	.0402V-31.6	.0380V-42.0	.0286V-42.7	.0248V-48.4	.0218V-54.0	.0193V-59.8	.0173V-65.5
96	.0486V-26.1	.0395V-31.6	.0373V-42.0	.0281V-42.7	.0244V-48.3	.0214V-54.0	.0190V-59.7	.0170V-65.5
98	.0478V-26.1	.0389V-31.6	.0367V-42.0	.0277V-42.6	.0240V-48.2	.0210V-53.9	.0187V-59.6	.0168V-65.4
100	.0470V-26.1	.0381V-31.5	.0361V-42.0	.0272V-42.6	.0236V-48.2	.0207V-53.8	.0185V-59.5	.0165V-65.3
102	.0462V-26.1	.0375V-31.5	.0356V-42.0	.0268V-42.5	.0233V-48.1	.0205V-53.8	.0182V-59.5	.0163V-65.2
104	.0454V-26.1	.0369V-31.5	.0350V-41.9	.0264V-42.5	.0229V-48.1	.0201V-53.7	.0179V-59.4	.0161V-65.1
106	.0446V-26.0	.0363V-31.5	.0345V-41.9	.0260V-42.5	.0226V-48.0	.0199V-53.7	.0177V-59.4	.0158V-65.1
108	.0439V-26.0	.0357V-31.4	.0339V-41.9	.0256V-42.4	.0222V-48.0	.0196V-53.6	.0174V-59.3	.0156V-65.0
110	.0432V-26.0	.0352V-31.4	.0335V-41.9	.0252V-42.4	.0219V-48.0	.0193V-53.6	.0172V-59.2	.0154V-64.9
112	.0425V-26.0	.0346V-31.4	.0330V-41.9	.0248V-42.4	.0216V-47.9	.0190V-53.5	.0169V-59.2	.0152V-64.9
114	.0419V-26.0	.0340V-31.4	.0325V-41.9	.0245V-42.3	.0213V-47.9	.0188V-53.5	.0167V-59.1	.0150V-64.8
116	.0412V-26.0	.0336V-31.3	.0320V-41.9	.0241V-42.3	.0210V-47.8	.0185V-53.4	.0165V-59.1	.0148V-64.7
118	.0406V-25.9	.0331V-31.3	.0316V-41.8	.0238V-42.3	.0207V-47.8	.0182V-53.4	.0163V-59.0	.0146V-64.7
120	.0400V-25.9	.0326V-31.3	.0311V-41.8	.0234V-42.2	.0204V-47.8	.0180V-53.3	.0160V-59.0	.0144V-64.6
122	.0394V-25.9	.0321V-31.3	.0307V-41.8	.0231V-42.2	.0201V-47.7	.0178V-53.3	.0158V-58.9	.0142V-64.6
124	.0388V-25.9	.0317V-31.3	.0303V-41.8	.0228V-42.2	.0199V-47.7	.0175V-53.2	.0156V-58.9	.0141V-64.5
126	.0383V-25.9	.0313V-31.3	.0299V-41.8	.0225V-42.1	.0196V-47.6	.0173V-53.2	.0154V-58.8	.0139V-64.4
128	.0378V-25.9	.0308V-31.2	.0295V-41.8	.0222V-42.1	.0194V-47.6	.0171V-53.2	.0152V-58.8	.0137V-64.4
130	.0372V-25.9	.0304V-31.2	.0291V-41.8	.0219V-42.1	.0191V-47.6	.0169V-53.1	.0151V-58.7	.0136V-64.3
132	.0367V-25.9	.0300V-31.2	.0288V-41.7	.0216V-42.1	.0189V-47.5	.0167V-53.1	.0149V-58.7	.0134V-64.3
134	.0362V-25.8	.0296V-31.2	.0284V-41.7	.0214V-42.0	.0186V-47.5	.0165V-53.0	.0147V-58.6	.0132V-64.2
136	.0358V-25.8	.0292V-31.2	.0280V-41.7	.0211V-42.0	.0184V-47.5	.0163V-53.0	.0145V-58.6	.0131V-64.2
138	.0353V-25.8	.0288V-31.1	.0277V-41.7	.0208V-42.0	.0182V-47.5	.0161V-53.0	.0144V-58.5	.0129V-64.1
140	.0348V-25.8	.0285V-31.1	.0274V-41.7	.0206V-42.0	.0180V-47.4	.0159V-52.9	.0142V-58.5	.0128V-64.1

PART 10 - IRRIGATION PUMPING PLANT EVALUATIONS

A. General Information

Field testing of irrigation pumping plants, especially those on deep wells, is a very complex and sometimes complicated procedure. It is essential to have the right equipment and experienced personnel in order to make accurate and reliable field tests.

B. Equipment

Generally, two types of equipment are necessary to test irrigation pumping plant efficiency.

1. Equipment that measures output work being done by the irrigation pump. The following are needed:

(a) A reliable water meter to measure the discharge rate of the pump.

(b) Gauges to measure the water level in the well, or other source, while the pump is operating.

(c) Pressure gauges to determine the discharge pressure or operating head at the pump.

2. Equipment which measures the input energy being used by the engine or motor which powers the irrigation pump. The following are needed:

(a) Equipment for natural gas-, diesel-, L.P.-, and gasoline-powered engines will require:

(1) A torque sensoring device to determine the brake horsepower delivered by the engine to operate the pump at a given RPM (revolutions per minute) level.

(2) A tachometer to measure RPM of the pump and/or engine.

(3) Means to measure fuel consumption.

(4) A stop watch to determine the amount of fuel being consumed by the internal combustion engine for a certain unit of time.

(b) Equipment for electric-powered plants will require:

(1) A stop watch to measure the number of kilowatt hours being consumed (meter reading).

(2) Panel devices such as an amp-volt meter and a power factor meter can be used to obtain electrical consumption, although special training is advised before using this equipment.

C. Theory Relating to Pumping Plant Efficiency

Some of the basic equations and conversions used for pump testing are:

$$\text{Water horsepower (whp)} = \frac{\text{Total Dynamic Head} \times \text{gpm}}{3960}$$

Where: Total Dynamic Head (T.D.H.) or Total Pumping Head = Depth to Pumping Water Level (ft.) + Column Head Loss (ft.) + Pressure Head (psi) x 2.31

gpm = gallons pumped/time in minutes

D. The Nebraska Performance Standard (NPS) 1/

1. This is one method to present and evaluate total pumping plant performance (total efficiency of engine or motor, pump drive, and pump) and to determine excess fuel use. The NPS is a set of criteria which represents the performance level at which a properly designed and tuned pumping plant should operate. The criteria is listed in units of whp-hrs. per unit of fuel. The base NPS for all fuel types before adjustment for pump bowl size and numbers and electric motor size is as follows:

Fuel Type	whp-hr. Unit of Energy	Energy Units
Natural Gas	61.7	1000 ft^3 (mcf)*
Diesel	12.5	Gallon
Propane	6.89	Gallon
Gasoline	8.66	Gallon
Electricity	0.885	kWh

*925 BTU/cu. ft. (BTU content can vary from one area to another.)

2. Common Adjustment Factors for Pumps are:

No. of Bowls	Adjustment Factor for 6" and 8" Bowls	Adjustment Factor for 10" and Larger Bowls
3 or more	1.02	1.07
2	0.988	1.06
1	0.948	1.02

3. Electric Motor Adjustment Factors:

Motor Size (HP)	Adjustment Factor
2.0 - 7.5	0.932
10 - 40	1.00
50 - 75	1.04
100 - 400	1.05

1/ Sometimes referred to as Nebraska Performance Criteria (NPC).

4. Equations used to determine NPS are as follows:

$$NPS = \text{Base NPS} \times \text{Adjustment Factor*} = \text{whp-hr./unit of fuel}$$

$$\text{Pump Plant Performance} = \text{whp} \div \text{Fuel Usage/hr.}$$

$$\text{Performance Rating} = \frac{\text{Pump Plant Performance} \times 100}{NPS}$$

*As determined in item 2, under D on page 10-2.

E. Fuel Consumption Computations

1. Diesel, propane, and gasoline

$$\frac{\text{Fuel Weight (lbs.)*} \times 3600}{\text{wt./gal.} \times \text{Time (seconds)}} = \text{gal./hr.}$$

Where: wt./gal. = weight of one gal. of fuel
= 7.1 lbs./gal. - No. 2 diesel
= 4.25 lbs./gal. - propane
= 6.15 lbs./gal. - gasoline

*Weight of fuel used.

2. Natural gas (mcf./hr.)

$$\text{mcf/hr.} = \frac{3.6 \times \text{Dial Cap.} \times \text{Dial Rev.}}{\text{Time (seconds)}} \times \text{Correction Factor}$$

Where:
mcf/hr. = thousand cubic feet per hour
Dial Cap. = meter dial capacity in cubic ft./revolution
Dial Rev. = No. of dial revolutions counted per time interval

$$\text{Correction Factor} = \frac{\text{ATM Pressure} + \text{Gauge Pressure}}{\text{ATM Pressure} + 0.25 \text{ psi}}$$

Where: ATM Pressure (psi) = Barometric Pressure (in Hg) x 0.4902 - Elevation Correction

(If actual ATM pressure is not available, determine the average ATM pressure.)

Average ATM Pressure = 14.72 - Elevation Correction
Elevation Correction = Elevation in thousand feet x 0.5 psi

or

$$\frac{\text{Elev. Ft. x 0.5}}{1000}$$

3. Electricity (kW) using a Watt hour meter

$$\text{kW} = \frac{3.6 \times \text{Disc Rev.} \times K_h \times \text{PTR} \times \text{CTR}}{\text{Time (seconds)}}$$

Where:

Disc Rev. = No. of Disc Revolutions
K_h = meter constant
PTR = Power Transformer Ratio: usually = 1
CTR = Current Transformer Ratio: usually = 1

F. Horsepower

$$\text{whp} = \frac{\text{T.D.H. x gpm}}{3960}$$

$$\text{bhp} = \frac{\text{whp}}{\text{Pump Efficiency x Drive Efficiency*}}$$

*Drive efficiency includes:

1. Gear head efficiency
2. Line shaft friction-loss
3. Thrust bearing loss

bhp output (electric motor) = 1.341 x kW input x motor efficiency

G. Input Horsepower (Ihp)

$$\text{Input horsepower} = \frac{\text{Fuel Use x Btu content of Fuel}}{2545}$$

$$\text{Nat. Gas - Input hp} = \frac{\text{cu.ft./hr. x 925}}{2545} = \text{cu.ft./hr. x 0.3635}$$

$$\text{Diesel - Input hp} = \frac{\text{gal./hr. x 140,000}}{2545} = \text{gal./hr. x 55}$$

$$\text{Propane - Input hp} = \frac{\text{gal./hr. x 92,000}}{2545} = \text{gal./hr. x 36.15}$$

Gasoline - Input hp = $\frac{\text{gal./hr. x 124,000}}{2545}$ = gal./hr. x 48.72

Electricity - Input hp = $\frac{4.82 \times \text{Disc Rev.} \times K_h}{\text{Time (seconds)}}$

or Input hp = 1.34 x Fuel Use (kW)

H. Efficiency

Engine Efficiency = $\frac{\text{Bhp}}{\text{Ihp}}$ x 100

Motor Efficiency = $\frac{\text{Motor hp output}}{\text{kW input} \times 1.34}$

or Assumed Motor Efficiencies

Submersible	Vertical Hollow Shaft	Belt Drives
	10-100 hp - 90%	10-40 hp - 88%
All motors - 80%	101-150 hp - 91%	41-125 hp - 89%
	151-300 hp - 92%	122-300 hp - 92%

Pump Efficiency = $\frac{\text{whp}}{\text{Bhp}}$ x 100 (internal combustion)

Pump Efficiency = Overall Efficiency ÷ Assumed Motor Efficiency x 100 (Electric)

Overall Efficiency = $\frac{\text{Whp}}{\text{Ihp}}$ x 100

Overall pumping plant efficiency for electric = $\frac{\text{gpm x total head (ft.)}}{\text{5300 x kW input}}$

I. Pumping Plant Evaluation - Procedure

1. Determine the total dynamic head. A water level indicator should be used to measure the depth to the water level in the well while the pump is operating. This is the distance from the water level to the centerline of the pump discharge pipe. The column head loss can be determined from the appropriate tables. (This can usually be neglected since it is a minor loss.) Add both of these values to the discharge head at the pump after converting it to feet by multiplying the pressure (psi) by 2.31. This will be the total dynamic head in feet.

2. Determine the pump discharge in gpm (gallons per minute). Use an accurate, reliable water meter--either an in-line propeller type or a pitot- or velocity-tube type.

3. Calculate the water horsepower (whp)

$$\text{whp} = \frac{\text{total dynamic head} \times \text{gpm}}{3960}$$

4. Determine the fuel consumption of the pumping plant:

Gallons/hr. for diesel, L.P. gas or gasoline
mcf (1,000 cu. ft.)/hr. for natural gas
kilowatt hours/hr. for electricity

5. Calculate the pumping plant performance in terms of water horsepower hours (whp-hrs.) per unit of fuel.

$$\text{whp-hrs. per unit of fuel} = \frac{\text{water horsepower}}{\text{fuel use per hour}}$$

6. Compare whp-hrs. per unit of fuel with the NPS.

$$\text{Pumping Plant Performance Rating} = \frac{\text{whp-hrs./unit of fuel}}{\text{performance standard (criteria)*}}$$

$$= \%\ \text{of Standard}$$

(The NPS is listed on page 10-2.)

*Adjusted as needed.

7. Excess Fuel Cost/Hour

$$= \frac{100 - \text{Performance Rating (\%)}}{100} \times \text{Energy Use Rate} \times \text{Fuel Cost/Unit}$$

x Annual Pumping Time (hrs.) = Annual savings possible if pumping plant raised to 100% of NPS

8. Determine pump and engine efficiencies

$$\text{Pump Efficiency} = \frac{\text{whp}}{\text{Bhp*}} \times 100$$

*Brake horsepower from torque cell readout

$$\text{Engine Efficiency} = \frac{\text{Bhp}}{\text{Ihp}} \times 100$$

9. Determine savings if pump efficiency is improved from E_1 to E_2

$$\text{Adjusted Percentage (A.P.)} = \frac{\text{Present Efficiency } (E_1)}{\text{Improved Efficiency } (E_2)} \times 100$$

$$\text{Savings} = \text{Annual Fuel Cost} \times (1 - \text{A.P.})$$

10. Determine savings by improving engine efficiency from E_1 to E_2

$$\text{A.P.} = \frac{\text{Present Engine Efficiency } (E_1)}{\text{Improved Engine Efficiency } (E_2)} \times 100$$

$$\text{Adjusted Fuel Use Rate} = \frac{\text{Original Use Rate} \times \text{Adjusted Percentage (A.P.)}}{100}$$

$$\text{Savings} = (\text{Original Use Rate} - \text{Adjusted Use Rate}) \times \text{Fuel Cost/Unit} \times \text{Annual Pumping Hours}$$

11. Sample Problem - Refer to following field sheets which show examples of a pumping plant evaluation using natural gas-, diesel-, propane-, and electric-powered units. For each evaluation use Form KS-ENG-20. For the fuel used, either use Form KS-ENG-20a (natural gas, diesel, or propane) or 20b (electric). A cost analysis of the pumping plant performance is on the reverse side of Forms KS-ENG-20a and 20b.

<u>Note</u>: In summary, it is not within the scope of this section to go into the detailed aspects of theory relating to pumping plant efficiencies and evaluations. There are several excellent manuals that have been recently published on these subjects. Anyone who plans to become actively involved in evaluations should obtain one or more of these manuals. They are:

1. "Irrigation Pumping Plant Performance Handbook," Fourth Edition, 1982, issued by the Agricultural Engineering Department, Cooperative Extension Service, University of Nebraska-Lincoln, Lincoln, Nebraska.

2. "Simplified Irrigation Pumping Plant Test Procedure Manual," First Edition, 1982, issued by the Agricultural Engineering Department, Cooperative Extension Service, University of Nebraska-Lincoln, Lincoln, Nebraska.

3. "Irrigation Pumping Plant Energy Efficiency Testing Procedure Manual," issued by the High Plains Underground Water Conservation District No. 1, 2930 Avenue Q, Lubbock, Texas.

Figure 10-1

IRRIGATION PUMPING PLANT EVALUATION

(To be used with Form KS-ENG-20a or KS-ENG-20b as applicable)

Name Example County ______
Legal Descr. ______ Date ______

Pumping head:

Depth to Pumping Water Level 208 ft.
Column Head Loss 2 ft.
Discharge Head, Pressure @ Well 10 psi x 2.31 = 23 ft.
Total Dynamic Head = 233 ft.

Well Discharge - Flow Meter:

Propeller Type: Time: 5 Min., 30 Sec., = 5.5 Min.
Gallons - Stop 7,458 , Gallons - Start 3,608 =
3,850 Total gallons ÷ Time, 5.5 Min. = 700 gpm

Pitot Tube Type: ID Pipe Dia. ______ in., Diff. Press ______ in., Q = ______ gpm
or Factor ______, Velocity ______ fps, Q = ______ gpm

Energy Use:

☒ Diesel Time: 10 min., 30 Sec. = 0.175 Hours
7.1 lbs./gal. Weight Start 20 lbs. - Weight Stop 15.21 lbs. =
or 4.79 Net Weight Used ÷ 7.1 lbs./gallon
☐ Propane ÷ 0.175 time in hours = 3.86 gal./hr.
4.25 lbs./gal

☐ Electric Time ____ min. 38 Sec. = 38 Seconds
3.6 x 10 Disc Revolutions x 57.6 K_h ÷ 38 Sec. =
54.6 kW, — Volts, — Amps

☐ Natural Gas Time 3 Min. 17.3 Sec. = 197.3 Seconds
3.6 x 5 Dial Capacity x 5 Dial Revolutions ÷
197.3 Seconds = 0.4562 x Correction Factor* 1.7132 =
0.7816 mcf/hr.

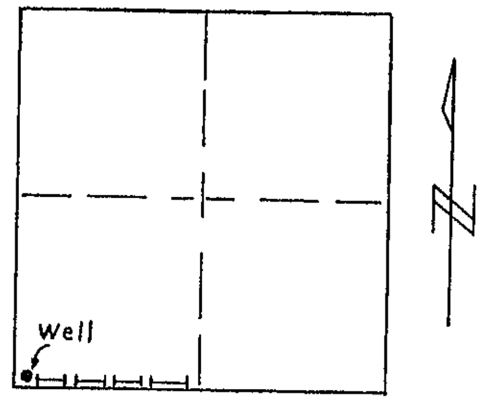
$$^{*}\text{Correction Factor} = \frac{\text{ATM Pressure + Gauge Pressure}}{\text{ATM Pressure + 0.25 psi}} = \frac{13.42 + 10.0}{13.42 + 0.25} = 1.7132$$

Average ATM Pressure + (14.72 - Elevation Correction) = 13.42

$$\text{Elevation Correction} = \frac{(\text{Elevation in feet x 0.5 psi})}{1{,}000} = 2.6 \times 0.5 = 1.3$$

$$\text{Water Horsepower (whp)} = \frac{\text{Q(gpm) x Total Dynamic Head (ft.)}}{3960} = \frac{700 \times 233}{3960} = 41.2$$

Irrigation Pumping Plant Data



Location Map
Scale 1" = 1,320'

Acres Irrigation by this well 80 acres
Type of Irrigation System Surface gravity

Pump Mfg. Johnston No. of Stages 4
Serial No. 9808 Bowl Setting —
Pump Shaft Dia. — Threads/In. —
Year Installed 1975 Column Size 8"
Pump Setting 240 ft., Line Shaft Dia. 1½"
Pump and Impeller Model No. 12cc
Impeller Trim Size Full Tail Pipe Length, ft. none
Well Driller Smith Drilling Co. Year Drilled 1975
Address Garden City, Kansas Well Depth 250
Drilled Dia. 26" Casing Dia. 16"
Size 10" and number 4 of bowls

Power Unit:
Mfg. Minneapolis-Moline Fuel Type Nat. Gas Year Installed 1975
Model No. HD504A-6A Displacement 504 in.^{3} Serial No. 03602781
Normal Operating Speed 1,400 RPM, Continuous Horsepower 83
Gearhead Type Randolf, F-100 Gearhead Ratio 3:4

Measured Data:
Pump RPM 1,760 Driver RPM 1,320 Static Water Level 192
Cascading Water none

ue Cell Readout:
3,151 in. lbs. RPM 1,320 BHP 66

ıa Hours 2,000
per mcf

Figure 10-2

PUMPING PLANT PERFORMANCE SUMMARY - FUEL Propane

(To be used with Form KS-ENG-20)

KS-ENG-20a
7/84

Name Example

Date ____________

From Sheet No. 1, Form KS-ENG-20

Water Horsepower (whp) = 41.2, Fuel Use 7.0 /hr, Q = 700 gpm

Total Dynamic Head (T.D.H.) = 233 ft, Criteria = 6.89 whp-hrs/gal.

Adjustment Factor = 1.07, Adjusted Criteria = Criteria x Adjustment Factor

Adjusted Criteria = 6.89 x 1.07 = 7.37 whp-hrs/mcf

Pumping Plant Performance Rating - Nebraska Standard

$$\text{Performance} = \frac{\text{whp}}{\text{Fuel Use}} \div \text{Adjusted Criteria} \times 100 = \frac{41.2}{7.0} \div 7.37 \times 100$$

$$= 80\ \%$$

Performance Rating - Pump and Engine

Brake Horsepower (bhp) - measured - torque cell readout = 66

$$\text{Pump Efficiency*} = \frac{\text{whp}}{\text{bhp}} \times 100 = \frac{41.2}{66} \times 100 = 62.4\ \%$$

$$\text{Input Horsepower (ihp)} = \frac{\text{Fuel Use (Cu.Ft./hr.)} \times \text{BTU content of fuel}}{2545}$$

$$= \frac{7.0 \times 92{,}000}{2545} = 253.0$$

$$\text{Thermal Efficiency of Engine*} = \frac{\text{bhp}}{\text{ihp}} \times 100 = \frac{66}{253.0} \times 100 = 26\ \%$$

$$\text{Overall Efficiency*} = \frac{\text{whp}}{\text{ihp}} \times 100 = \frac{41.2}{253.0} \times 100 = 16.3\ \%$$

*Optimum efficiencies should run as follows:

	Natural Gas	Diesel	Propane
Pump	75 - 80%	75 - 80%	75 - 80%
Engine	24 - 28%	28 - 32%	28 - 32%
Overall	17%	23%	18%

COST ANALYSIS - PUMPING PLANT PERFORMANCE

Name Example
Date ________

Nebraska Criteria:

Excess Fuel Used Annually - Fuel Cost = 0.65 per gallon

Excess Fuel Cost/Hr. = $\frac{100 - \text{Perfor. Rating (\%)}}{100}$ x Energy Use Rate =

$\frac{100 - 80}{100}$ x 7.0 = 1.4 x 0.65 Fuel Cost = 0.91

Annual Savings Possible = (Annual Pumping Hours) x (Excess Fuel Cost/Hr.)

= 2,000 x 0.91 = $1,820

Reduce Pumping Costs by Improving Pump Efficiency from 62.4 to 80%

$\frac{\text{Present Pump Effic.}}{\text{Improved Pump Effic.}}$ x 100 = $\frac{62.4}{80}$ x 100 = 78 Adjusted Percentage

Annual Fuel Cost = 7.0 Fuel Use/Hr. x 0.65 Fuel Cost/Unit
x 2,000 Annual Pumping Hours = $9,100

Savings = (100 - Adjusted Percentage) ÷ 100 x Annual Fuel Cost
= (100 - 78) ÷ 100 x 9,100 = $2,002

Reduce Pumping Costs by Improving Engine Efficiency from 26 to 32

$\frac{\text{Present Engine Effic.}}{\text{Improved Engine Effic.}}$ x 100 = $\frac{26.0}{32.0}$ x 100 = 81.3 Adjusted Percentage

Adjusted Fuel Use Rate = Original Use Rate x Adjusted Percentage ÷ 100
7.0 x 81.3 ÷ 100 = 5.69

Savings = (Original Use Rate - Adjusted Use Rate) x Fuel Cost/Unit
7.0 - 5.69 x 0.65
= 0.85 /Hr. x Annual Pumping Hrs. 2,000 = $1,700

Figure 10-3

PUMPING PLANT PERFORMANCE SUMMARY - FUEL - Natural Gas

KS-ENG-20a
7/84

(To be used with Form KS-ENG-20)

Name Example

Date ____________

From Sheet No. 1, Form KS-ENG-20

Water Horsepower (whp) = 41.2, Fuel Use 0.7816 /hr, Q = 700 gpm

Total Dynamic Head (T.D.H.) = 233 ft, Criteria = 61.7 whp-hrs/mcf

Adjustment Factor = 1.07, Adjusted Criteria = Criteria x Adjustment Factor

Adjusted Criteria = 61.7 x 1.07 = 66.0 whp-hrs/mcf

Pumping Plant Performance Rating - Nebraska Standard

Performance = $\frac{\text{whp}}{\text{Fuel Use}} \div$ Adjusted Criteria x 100 = $\frac{41.2}{0.7816} \div 66.0 \times 100$

= 79.9 %

Performance Rating - Pump and Engine

Brake Horsepower (bhp) - measured - torque cell readout = 66

Pump Efficiency* = $\frac{\text{whp}}{\text{bhp}} \times 100 = \frac{41.2}{66} \times 100 =$ 62.4 %

Input Horsepower (ihp) = $\frac{\text{Fuel Use (Cu.Ft./hr.) x BTU content of fuel}}{2545}$

$= \frac{781.6 \times 925}{2545} =$ 284.1

Thermal Efficiency of Engine* = $\frac{\text{bhp}}{\text{ihp}} \times 100 = \frac{66}{284.1} \times 100 =$ 23.2 %

Overall Efficiency* = $\frac{\text{whp}}{\text{ihp}} \times 100 = \frac{41.2}{284.1} \times 100 =$ 14.5 %

*Optimum efficiencies should run as follows:

	Natural Gas	Diesel	Propane
Pump	75 - 80%	75 - 80%	75 - 80%
Engine	24 - 28%	28 - 32%	28 - 32%
Overall	17%	23%	18%

COST ANALYSIS - PUMPING PLANT PERFORMANCE

Name Example

Date ____________

Nebraska Criteria:

Excess Fuel Used Annually - Fuel Cost = \$2.50 per mcf

Excess Fuel Cost/Hr. = $\frac{100 - \text{Perfor. Rating (\%)}}{100}$ x Energy Use Rate =

$\frac{100 - 79.9}{100}$ x 0.7816 = 0.1571 x 2.50 Fuel Cost = 0.3927

Annual Savings Possible = (Annual Pumping Hours) x (Excess Fuel Cost/Hr.)

= 2,000 x 0.3927 = \$785.40

Reduce Pumping Costs by Improving Pump Efficiency from 62.4 to 80

$\frac{\text{Present Pump Effic.}}{\text{Improved Pump Effic.}}$ x 100 = $\frac{62.4}{80.0}$ x 100 = 78 Adjusted Percentage

Annual Fuel Cost = 0.7816 Fuel Use/Hr. x 2.50 Fuel Cost/Unit

x 2,000 Annual Pumping Hours = \$3,908

Savings = (100 - Adjusted Percentage) ÷ 100 x Annual Fuel Cost

= (100 - 78) ÷ 100 x 3,908 = \$859.76

Reduce Pumping Costs by Improving Engine Efficiency from 23.2 to 28

$\frac{\text{Present Engine Effic.}}{\text{Improved Engine Effic.}}$ x 100 = $\frac{23.2}{28}$ x 100 = 82.86 Adjusted Percentage

Adjusted Fuel Use Rate = Original Use Rate x Adjusted Percentage ÷ 100

0.7816 x 82.86 ÷ 100 = 0.6476

Savings = (Original Use Rate - Adjusted Use Rate) x Fuel Cost/Unit

0.7816 - 0.6476 x 2.50

= 0.335 /Hr. x Annual Pumping Hrs. 2,000 = \$670.00

Figure 10-4

PUMPING PLANT PERFORMANCE SUMMARY - FUEL Diesel

(To be used with Form KS-ENG-20)

KS-ENG-20a
7/84

Name Example

Date ____________

From Sheet No. 1, Form KS-ENG-20

Water Horsepower (whp) = 41.2, Fuel Use 3.86 /hr, Q = 700 gpm

Total Dynamic Head (T.D.H.) = 233 ft, Criteria = 12.5 whp-hrs/gal.

Adjustment Factor = 1.07, Adjusted Criteria = Criteria x Adjustment Factor

Adjusted Criteria = 12.5 x 1.07 = 13.38 whp-hrs/mcf

Pumping Plant Performance Rating - Nebraska Standard

$$\text{Performance} = \frac{\text{whp}}{\text{Fuel Use}} \div \text{Adjusted Criteria} \times 100 = \frac{41.2}{3.86} \div 13.38 \times 100$$

$$= 79.8\ \%$$

Performance Rating - Pump and Engine

Brake Horsepower (bhp) - measured - torque cell readout = 66

$$\text{Pump Efficiency*} = \frac{\text{whp}}{\text{bhp}} \times 100 = \frac{41.2}{66} \times 100 = 62.4\ \%$$

$$\text{Input Horsepower (ihp)} = \frac{\text{Fuel Use (Cu.Ft./hr.)} \times \text{BTU content of fuel}}{2545}$$

$$= \frac{3.86 \times 140{,}000}{2545} = 212.3$$

$$\text{Thermal Efficiency of Engine*} = \frac{\text{bhp}}{\text{ihp}} \times 100 = \frac{66}{212.3} \times 100 = 31\ \%$$

$$\text{Overall Efficiency*} = \frac{\text{whp}}{\text{ihp}} \times 100 = \frac{41.2}{212.3} \times 100 = 19.4\ \%$$

*Optimum efficiencies should run as follows:

	Natural Gas	Diesel	Propane
Pump	75 - 80%	75 - 80%	75 - 80%
Engine	24 - 28%	28 - 32%	28 - 32%
Overall	17%	23%	18%

COST ANALYSIS - PUMPING PLANT PERFORMANCE

Name Example

Date ______

Nebraska Criteria:

Excess Fuel Used Annually - Fuel Cost = 1.00 per gallon

Excess Fuel Cost/Hr. = $\frac{100 - \text{Perfor. Rating (\%)}}{100}$ x Energy Use Rate =

$\frac{100 - 80.7}{100}$ x 3.86 = 0.74498 x $1.00 Fuel Cost = $0.745

Annual Savings Possible = (Annual Pumping Hours) x (Excess Fuel Cost/Hr.)

= 2,000 x 0.745 = $1,490

Reduce Pumping Costs by Improving Pump Efficiency from 62.4 to 80 %

$\frac{\text{Present Pump Effic.}}{\text{Improved Pump Effic.}}$ x 100 = $\frac{62.4}{80}$ x 100 = 78 Adjusted Percentage

Annual Fuel Cost = 3.86 Fuel Use/Hr. x 1.00 Fuel Cost/Unit

x 2,000 Annual Pumping Hours = $7,720

Savings = (100 - Adjusted Percentage) ÷ 100 x Annual Fuel Cost

= (100 - 78.0) ÷ 100 x 7,720 = $1,698

Reduce Pumping Costs by Improving Engine Efficiency from 31 to 32

$\frac{\text{Present Engine Effic.}}{\text{Improved Engine Effic.}}$ x 100 = $\frac{31}{32}$ x 100 = 97 Adjusted Percentage

Adjusted Fuel Use Rate = Original Use Rate x Adjusted Percentage ÷ 100

3.86 x 97 ÷ 100 = 3.74

Original Use Rate - Adjusted Use Rate) x Fuel Cost/Unit

3.86 - 3.74 x 1.00

0.12 /Hr. x Annual Pumping Hrs. 2,000 = $240

Figure 10-5

PUMPING PLANT PERFORMANCE SUMMARY - ELECTRIC

(To be used with Form KS-ENG-20)

KS-ENG-20b
7/84

Name Example

Date ______

From Sheet No. 1, Form KS-ENG-20

Water Horsepower (whp) = 41.2

Fuel Use = 54.6 kWh, Total Dynamic Head (T.D.H.) = 233 ft., Q = 700 gpm

Kh factor = 57.6, Disc. Rev = 10, Time = 38 Secs.

Criteria = 0.885 whp-hrs/kW

Adjusted Criteria = 0.885 x 1.07 = 0.947 whp-hrs/kW

Pumping Plant Performance Rating - Nebraska Standard

Performance = $\frac{\text{whp}}{\text{Fuel Use}}$ ÷ Adjusted Criteria x 100 = $\frac{41.2}{54.6}$ ÷ 0.947 x 100

= 79.7 %

Performance Rating - Pump and Engine

Size Motor 75 hp (from nameplate)

Input Horsepower (ihp) = $\frac{\text{4.82 x Disc. Rev. x Kh}}{\text{Time (Secs.)}}$ = $\frac{4.82 \times 10 \times 57.6}{38}$

= 73.1

or ihp = 1.34 x Fuel Use 54.6 kW = 73.2

Overall Eff. (O.E.)1/ = whp ÷ ihp x 100 = 41.2 ÷ 73.1 x 100 = 56.4 %

Pump Efficiency1/ = O.E ÷ Assumed Motor Efficiency2/ x 100

= 56.4 ÷ 90 x 100 = 62.7 %

1/ Optimum Efficiencies

Overall - 66%

Pump - 75-80%

2/ Assumed Motor Efficiencies:

Submersible	Vertical Hollowshaft	Belt Drives
All Motors - 80%	10-100 hp - 90%	10-40 hp - 88%
	101-150 hp - 91%	41-125 hp - 89%
	151-300 hp - 92%	126-300 hp - 92%

COST ANALYSIS - PUMPING PLANT PERFORMANCE

Name Example

Date ______

Nebraska Criteria:

Excess Fuel Used Annually - Fuel Cost = 0.035 per KW

Excess Fuel Cost/Hr. = $\frac{100 - \text{Perfor. Rating (\%)}}{100}$ x Energy Use Rate =

$\frac{100 - 79.7}{100}$ x 54.6 = 11.0838 x 0.035 Fuel Cost = 0.388

Annual Savings Possible = (Annual Pumping Hours) x (Excess Fuel Cost/Hr.)

= 2,000 x 0.388 = $ 776

Reduce Pumping Costs by Improving Pump Efficiency from 62.7 to 80

$\frac{\text{Present Pump Effic.}}{\text{Improved Pump Effic.}}$ x 100 = $\frac{62.7}{80}$ x 100 = 78.4 Adjusted Percentage

Annual Fuel Cost = 54.6 Fuel Use/Hr. x 0.035 Fuel Cost/Unit
x 2,000 Annual Pumping Hours = $ 3,822

Savings = (100 - Adjusted Percentage) ÷ 100 x Annual Fuel Cost
= (100 - 78.4) ÷ 100 x 3,822 = $ 825

U.S. Government Printing Office 1985 — 565-487